

ENERGY ENGINEERING ANALYSIS PROGRAM
REDSTONE ARSENAL, ALABAMA
ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS

FINAL REPORT

JUNE, 1987

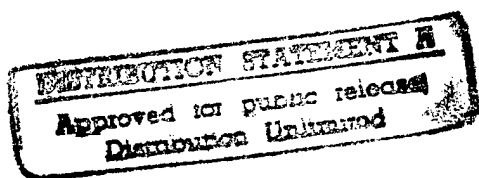
VOLUME I - EXECUTIVE SUMMARY

Prepared for

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By

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BENATECH, INC.

Engineering & Energy Consultants

1215 HIGHTOWER TRAIL

SUITE D-220

ATLANTA, GEORGIA 30350

ARMY CONTRACT NO. DACA01-85-C-0131,

PART I & II DTIC QUALITY INSPECTED 3



DEPARTMENT OF THE ARMY
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TABLE OF CONTENTS

VOLUME I - EXECUTIVE SUMMARY

TITLE	PAGE
.....	
1. INTRODUCTION	1
1.1 BACKGROUND	1
1.2 SCOPE	1
2. ENERGY CONSERVATION OPPORTUNITIES	2
2.1 TECHNICAL APPROACH	2
2.2 ECOs ANALYSES	2
3. RESULTS, CONCLUSIONS, AND RECOMMENDATIONS	8
3.1 RESULTS	8
3.2 CONCLUSIONS	8
3.3 RECOMMENDATIONS	17

TABLE OF VOLUMES

VOLUME I - EXECUTIVE SUMMARY

TITLE	PAGE
.....	
INTRODUCTION	1
ENERGY CONSERVATION OPPORTUNITIES	2
RESULTS, CONCLUSIONS, AND RECOMMENDATIONS	8

VOLUME II - NARRATIVE

TITLE	SECTION
.....	
EXECUTIVE SUMMARY	
INTRODUCTION	1
EXISTING CONDITIONS	2
WORK ACCOMPLISHED	3
ENERGY CONSERVATION OPPORTUNITIES EVALUAT	4
ENERGY STUDIES BY OTHERS	5
CONCLUSIONS	6
RECOMMENDATIONS	7

APPENDIX A

APPENDIX A - CONTRACT SCOPE OF WORK

TITLE	PAGE
.....	
CONTRACT SCOPE OF WORK	1
CORRESPONDENCE	26

VOLUME IV

APPENDIX B - PROJECT DOCUMENTATION

TITLE	PAGE
.....	
BOILER OPTIMIZATION	1
CHILLER OPTIMIZATION	90
CHILLER ECONOMIZER	131
COMPLETE CHILLER OPTIMIZATION	145

VOLUME V

APPENDIX C - BOILER ECOs BOOK 1 OF 3

ECO TITLE	PAGE
.....	
BOILER TUNE-UP	1
BURNER REPLACEMENT	87
REPLACEMENT BOILER	173
SUMMER BOILER INSTALLATION	249

VOLUME VI

APPENDIX C - BOILER ECOs BOOK 2 OF 3

ECO TITLE	PAGE
.....	
DOWNSIZE BOILERS	299
PREHEAT COMBUSTION AIR	363
BOILER FEEDWATER ECONOMIZER	458

VOLUME VII APPENDIX C - BOILER ECOs BOOK 3 OF 3

ECO TITLE	PAGE
.....	
STEEL FEEDWATER ECONOMIZER	549
OXYGEN TRIM SYSTEM	638
VARIABLE SPEED FANS	742
INSTALLATION OF TURBULATORS	769

VOLUME VIII APPENDIX C - CHILLER ECOs BOOK 1 OF 2

ECO TITLE	PAGE
.....	
CONDENSER TUBE CLEANING	1
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	82
WATER TREATMENT/FILL REPLACEMENT	200

VOLUME IX APPENDIX C - CHILLER ECOs BOOK 2 OF 2

ECO TITLE	PAGE
.....	
CHILLER SHUTDOWN	288
TWO-SPEED COOLING TOWER FAN	309
CENTRIFUGAL CHILLER REPLACEMENT	351
STEAM DRIVEN VS. ELECTRIC DRIVEN CHILLERS	356
WATERSIDE ECONOMIZER	364
CHILLED WATER TEMPERATURE RESET	441
VARIABLE SPEED PUMPING	493

VOLUME X APPENDIX E - BOILER EFFICIENCY CALCULATIONS

ECO TITLE	PAGE
.....	
TESTED COMBUSTION EFFICIENCY	1
TUNED FOR TESTED LOAD CONDITIONS	57
TUNED FOR AVERAGE LOAD CONDITIONS	107
TUNED FOR SUMMER LOAD CONDITIONS	163

VOLUME XI APPENDIX F - PERFORMANCE TESTING

ECO TITLE	PAGE
.....	
CHILLER TESTING	1
BOILER TESTING	51

1. INTRODUCTION

1.1 BACKGROUND

This report is the prefinal report of an Energy Engineering Analysis Program (EEAP) study of boilers and chillers at Redstone Arsenal, Huntsville, Alabama. Work was begun January, 1986 on the project by BENATECH, INC. under Contract No. DACA01-85-C-0131, Parts I and II, with the Mobile District, U.S. Army Corps of Engineers, Mobile, Alabama. The following activities have been accomplished:

- A detailed field investigation has been conducted.
- ECO calculations have been performed and ECIP analyses have been accomplished.
- Interim Report has been submitted.
- Low Cost/No Cost project documentation packages have been compiled.
- Prefinal Report is complete and submitted for review.

1.2 SCOPE

The Scope of Work specified in contract no. DACA01-85-C-0131, Parts I and II (and included in this report in Appendix A) requires the performance of a specific energy study. The Energy Conservation Opportunities analyzed under this study will serve as part of Redstone Arsenal's overall effort to reduce basewide energy use in accordance with the objectives set forth in the Army Energy Plan. The contract Scope of Work (SOW) for Redstone Arsenal outlines the following specific requirements:

- Determine the efficiency of the boiler/chiller plants by appropriate tests.
- Survey the boiler/chiller plants to determine if efficiency can be improved by the repair, addition, or modification of equipment and recommend improvements.
- Evaluate the control system and recommend changes, repairs, or new controls which will improve the efficiency of the plant.
- Review operation and maintenance procedures and provide site-specific recommendations which will increase the efficiency of the plants to the maximum level.
- Prepare a comprehensive report to document the work performed, the

results, and recommendations.

All of these Scope of Work items have been accomplished.

2. ENERGY CONSERVATION OPPORTUNITIES (ECOs)

2.1 TECHNICAL APPROACH

The Scope of Work contains a list of specific ECOs to be studied for Redstone Arsenal Boilers and Chillers. These ECOs were investigated after completing our field survey visits and compiling the raw data from the visits. The steps in collecting the field data are:

- Obtain nameplate data and methods of operation for the boilers and chillers.
- Inspect types and conditions of control systems.
- Take field measurements on boilers and chillers.

Using the field data, the various ECOs were analyzed for their feasibility of being enacted under Army guidelines.

2.2 ECOs ANALYSES

2.2.1 BOILERS

Boiler Feedwater Economizer.

This ECO investigates the energy savings achievable by preheating the boiler feedwater with recovered waste heat from the flue gas. Borosilicate heat exchangers are used so that potential corrosion problems are reduced in the temperature range between 100 F - 150 F. Feedwater economizers already exist in Building 3624, although these devices were inoperable when the boilers were surveyed.

Burner Replacement.

This ECO analyzes the energy savings achievable by replacing existing burners with modulating, cam-type burners. These burners modulate the air-to-fuel ratio as a function of boiler load. This modulation results in a combustion efficiency of approximately 80% over the operating range of the boiler. This ECO is not applicable to boilers in Buildings 3624 and 4725 which already employ modulating burners.

in the temperature range between 100 F - 150 F. Feedwater economizers already exist in Building 3624, although these devices were inoperable when the boilers were surveyed.

Boiler Tune-Up.

This ECO evaluates the potential for energy savings by performing semi-annual boiler tune-ups. The boilers should be tuned for minimum excess air at their respective average operating loads. A well-tuned boiler operates at its peak combustion efficiency at the load for which it is tuned.

Preheat Combustion Air.

The purpose of this ECO is to use waste heat recovered from the flue gas in order to preheat combustion air. Boiler efficiency can be improved by implementing this technique. For this ECO, improved combustion efficiencies are calculated using the higher preheated inlet air temperature; however, all other test conditions remain the same as the existing test conditions. Preheaters already exist in Building 4725. Borosilicate heat exchangers are used so that corrosion problems are reduced in the temperature range between 100 F - 150 F.

"Summer" Boiler.

This ECO analyzes the potential of installing a boiler to handle the steam production requirements during the "summer" months. The boiler fuel consumption and operating logs were examined to isolate the steam capacity requirements for each month. It was determined that during the period of May 16 - October 15, the boiler demands were at their minimum levels. The "summer" boilers were then sized to meet these average summer loads. The energy savings are realized in the increased efficiency of the new boilers (approximately 80%) as compared with the underloaded (in summer operation) existing boilers.

Variable-Speed Motor Drives.

This ECO analyzes the potential for savings by installing inverters on combustion air fan motors. Inverters save energy by controlling the fan power in response to actual air flow requirements.

Boiler Replacement.

This ECO evaluates the savings to be achieved by replacing the existing boiler with a new, 80% efficient boiler of the same size.

Downsize Boilers.

This ECO analyzes the energy savings that could be achieved by installing smaller boilers designed to meet the average operating load of the boiler plant. This ECO is applicable to boiler plants which are operating in underloaded conditions. The savings to be realized result from the increased efficiencies (approximately 80%) of the new boilers as compared with the existing underloaded boilers.

Installation of Turbulators.

This ECO analyzes the energy savings achievable by installing turbulators in fire-tube boilers. Turbulators are baffles which create turbulent flow in the core of hot combustion gases. This turbulent flow maximizes heat transfer from combustion gases through the tube walls to the boiler water. Thus, more heat is used in the generation of steam and less is lost out the exhaust stack. Fuel savings of 1% can be achieved by installing turbulators in fire-tube boilers. This ECO is not applicable to water-tube boilers. The use of Fuel Efficiency, Inc. information does not constitute an endorsement of their product, but merely an actual representation of achievable performance levels.

Oxygen Trim System.

The purpose of an oxygen trim system is to control the air/fuel ratio of a boiler within the most efficient operating parameters. This is achieved by using an oxygen analyzer in the flue stack in conjunction with a microprocessor controller. The oxygen analyzer measures the oxygen content in the flue gas, and a potentiometer monitors the fuel flow rate. The microprocessor controls adjust the air flow damper in order to get the most efficient combustion process. The use of Westinghouse "Veritrim" oxygen analyzer and control information does not constitute an endorsement of their product, but merely an actual representation of achievable performance levels.

Steel Feedwater Economizer.

This ECO investigates the energy savings achievable by preheating the boiler feedwater with recovered waste heat from the flue gas. Alloy steel heat exchangers are used so that potential corrosion problems are reduced

2.2.2 CHILLERS

Automatic Chiller Tube Cleaning.

This ECO establishes representative savings which result from the installation of an on-line condenser tube cleaning system. This system uses slightly oversized brushes fitted into each condenser tube to remove rust and deposits. The brushing action is initiated by a diverter valve, which changes the direction of water flow, pushing the brushes to either end of the condenser. Flow through the condenser automatically changes. Savings result from improved heat transfer from the condenser water through the condenser tube wall. The savings were calculated using manufacturers' data. The use of Water Services of America and ATB information does not constitute an endorsement of their product, but merely an actual representation of achievable performance levels.

Condenser Tube Cleaning.

This ECO analyzes the potential for savings by manually cleaning condenser tubes. This operation reduces the tube fouling factor to its minimum achievable value. Reduced fouling factor results in increased heat transfer capabilities of the system, and consequently less energy is required to achieve the same cooling capacity.

Chiller Shutdown.

This ECO analyzes the energy savings achievable when equipment is operated only when it is needed to provide comfort conditioning. The savings are calculated for chillers (partially loaded), chilled water and condenser water pumps, and the cooling tower. No credit is taken for reheating or air handling savings which will also result. The methodology used to calculate the savings is shown in "Standardized EMCS Energy Savings Calculations", CR 82.030, September 1982.

Chilled Water Temperature Reset.

This ECO analyzes the energy savings resulting from resetting the chilled water supply temperature upward, without appreciably affecting comfort conditions. Savings result from decreasing the demand on the chiller compressor, and therefore, the amount of energy input to the chiller. The methodology used to calculate the savings is shown in the "Standardized EMCS Energy Savings Calculations", CR 82.030, September 1982.

Water Treatment/Fill Replacement

This ECO analyzes the energy savings resulting from maximizing cooling tower performance. Water treatment and replacement of cooling tower fill are offered as one composite ECO, because one recommendation will improve and maintain the savings of the other. Considered separately, neither will offer long term savings. Replacing deteriorated cooling tower fill PVC polymer will ensure that the condenser water will flow through the cooling tower and achieve even distribution and maximum heat transfer with the air. Introduction of water treatment will maintain the desirable effects of the new fill, but will offer no improvement with the existing cooling tower fill. The reduction in condenser water supply temperature will result in reduced compressor load. The methodology used is similar to Chilled Water Temperature Reset. ECO's are presented for the buildings with the highest SIRs. The methodology used to calculate the savings is shown in the "Standardized EMCS Energy Savings Calculations", CR82.030, September 1982.

Waterside Economizer

This ECO evaluates the feasibility of installing a plate heat exchanger, new valves and controls to enable the chiller to be shutdown during periods of the year when the wet bulb temperatures will provide sufficient evaporative cooling effect. Building load fluctuates with internal and external loads. During the fall, winter, and spring, the external cooling loads on a building are at a minimum. During these seasons, the wet bulb temperatures are low enough to maintain evaporation in sufficient quantity to provide condenser water cold enough to meet the internal loads of the building. The analysis utilizes cooling tower performance data used to determine the expected cooling tower water temperatures for a given wet bulb temperature. It was recommended by plate heat exchanger sales representative (for analysis purposes) to use a heat exchanger with a four degree approach temperature because it is less expensive. It was assumed that the building loads could be adequately met with chilled water supply temperatures between 48 and 44 degrees F. In addition, the cooling tower is assumed to cycle half the time for all those hours when the cooling tower is less than 40 degrees F. The cooling tower will cycle off and on to prevent the cooling tower from freezing. This bin hour calculation determines the electrical savings resulting from shutting down the chiller (partially loaded) and the cooling tower when it is possible to do so. The

methodology used to calculate the savings is shown in "Standardized EMCS Energy Savings Calculations", CR 82.030, September 1982. The use of Marley and Mueller manufacturer's data does not constitute an endorsement of their product but merely an actual representation of achievable performance levels.

Variable Speed Pumping

This ECO analyzes the energy savings potential of installing variable speed pumping (accomplished with the installation of a variable frequency drive) in place of the existing constant speed pumping. Included with the installation of a variable speed drive is the replacement of all three-way valves with two-way valves and a differential pressure control system. Electrical energy is saved when the amount of energy devoted to pumping chilled water is varied as the cooling load on the building. It was assumed that the pump speed is proportional to the building load. The power required to operate the pump varies as the cube of the speed. Savings are determined by calculating the energy required for constant speed pumping and subtracting the energy necessary to operate the variable speed pump. The methodology used to calculate the savings is shown in ASHRAE Equipment 1983.

Two Speed Cooling Tower Fans

This ECO examines the energy savings resulting from replacing the constant speed cooling tower fan motor with a two speed motor. Savings result from the fan law which states that the power required to operate a fan varies as the cube of the fan speed. The methodology used to calculate the savings is shown in "Heating, Ventilating and Air Conditioning", Parker and McQuistone, 1982.

3. RESULTS, CONCLUSIONS AND RECOMMENDATIONS

3.1 RESULTS

A complete listing of all Boiler ECO's and OMR's is provided in Table ES 1. This is sorted by SIR. A similar list for all Chiller ECOs and OMRs is shown in Table ES 2, sorted according to SIR.

All ECOs with SIRs greater than 1.0 were considered for project packaging.

3.2 CONCLUSIONS

Candidate ECOs for project packaging are show in Table ES 3 and ES 4. Both tables are sorted by Boiler/Chiller number and descending SIR for each boiler or chiller. BENATECH combined ECOs into projects to be implemented on a per boiler/chiller basis. This strategy allows for projects with low construction costs to be funded on a local level.

For a given boiler of chiller, some of the recommended ECOs were mutually exclusive. An example of two mutually exclusive ECOs are "Preheat Combustion Air" and "Steel Feedwater Economizer". Both of these ECOs function to recover waste heat from boiler exhaust gases. In a case where two ECOs indpendently have SIRs greater than 1.0, but are mutually exclusive, BENATECH used good engineering judgement to select the ECO yielding maximum energy savings.

Project synergy calculations between candidate boiler ECOs begins with the average boiler load (MBTU). Each "Step" is explained below:

Step 1. Calculations start with the determination of the Annual Savings. Annual savings are calculated in one of three ways:

- a.) For ECOs where a nominal percentage reduction of energy consumption is known, the annual savings are calculated as shown below:

$$(\% \text{ reduction})(\text{average boiler load}) = \text{Annual Savings (MBTU/yr.)}$$

Applicable ECOs: Turbulators

- b.) In the cases where the expected boiler efficiency is used to calculate the annual savings as shown below:

$$\begin{aligned} & (\text{average boiler load}) [1 - (\text{average boiler eff.} / \text{expected boiler eff.})] \\ & = \text{Annual Savings (MBTU/yr.)} \end{aligned}$$

Applicable ECOs: Burner Replacement

- c.) In the case of recommendation swher the consumption reduction is calculated in the ECO, the annual savings equals the expected consumption reduction.

Applicable ECOs: Summer Boiler, Boiler Tune-up

Second, the Annual Fuel Consumption is calculated by subtracting the annual savings from the average boiler load.

Third, the Boiler Efficiency is recalculated using the following formula:

$$(\text{average boiler efficiency}) / [1 - (\text{annual savings} / \text{average boiler load})]$$

Step 2, Step 3. The calculations for these steps are performed iteratively based on the number of analytical **Steps** in the project.

Per guidance received in the Prefinal Review Meeting, several ECOs identified by BENATECH had already been implemented, are currently in progress, or already have programming documentation in place. Given this information, BENATECH prepared low cost/no cost project documentation for all remaining recommended ECOs.

TABLE ES 1 - BOILER ECOs EVALUATED SORTED BY SIR

ECO	Boiler No.	Life (YRS)	MBTUs Saved			Annual Savings	Cost Estimate	SIR	Simple Payback (Years)
			Elec. MBTUs	Nat. Gas MBTUs	#2 Oil MBTUs				
Boiler Tune-Up OMR	4725 -3	15		57931		\$251,998	\$2,705	1341.68	0
Boiler Tune-Up OMR	3624 -4	10		34338		\$149,372	\$2,705	518.52	0
Boiler Tune-Up OMR	4725 -2	15		21293		\$92,626	\$2,705	495.49	0
Boiler Tune-Up OMR	3624 -3	10		8599		\$37,407	\$2,705	124.60	0
Boiler Tune-Up OMR	4725 -1	15		1945		\$8,460	\$2,705	36.27	0
Boiler Tune-Up OMR	3624 -1	10		2449		\$10,655	\$2,705	30.48	0
Boiler Tune-Up OMR	8977 -1	10		1965		\$8,548	\$2,705	23.08	0
Boiler Tune-Up OMR	115 -2	25		903		\$3,927	\$2,705	21.18	1
Boiler Tune-Up OMR	8028 -2	25			529	\$3,125	\$2,705	19.21	1
Turbulator Installation	8028 -2	25			98	\$579	\$861	12.43	1
Turbulator Installation	115 -2	25		120		\$522	\$1,295	9.10	3
Burner Replacement	115 -2	25		977		\$4,248	\$11,622	8.26	3
Turbulator Installation	7579 -1	10		156		\$679	\$861	7.50	1
Boiler Tune-Up OMR	7105 -4	10		925		\$4,025	\$2,705	7.16	1
Turbulator Installation	8874 -1	15			49	\$290	\$518	6.82	2
Turbulator Installation	7153 -1	5		82		\$357	\$287	5.64	1
Oxygen Trim System	8028 -2	25			853	\$5,041	\$16,420	5.49	3
Boiler Tune-Up OMR	3624 -2	10		748		\$3,254	\$2,705	4.45	1
Turbulator Installation	7105 -3	25		69		\$300	\$1,723	3.93	6
Turbulator Installation	8874 -2	15			28	\$165	\$518	3.90	3
Burner Replacement	7579 -1	10		858		\$3,734	\$10,319	3.44	3
Downsize Boiler	115 -2	25		1,488		\$6,475	\$45,285	3.23	7
Burner Replacement	8977 -1	10		749		\$3,257	\$10,319	3.00	3
Burner Replacement	7105 -3	25		413		\$1,795	\$13,575	2.99	8
Burner Replacement	8874 -1	15			319	\$1,882	\$9,017	2.55	5
Turbulator Installation	8977 -1	10		52		\$226	\$861	2.50	4
Summer Boilers	115 -2	25		559		\$2,430	\$25,478	2.16	11
Turbulator Installation	7105 -4	10		86		\$374	\$1,723	2.07	5
Downsize Boiler	7105 -3	25		774		\$3,368	\$40,907	1.86	12
Turbulator Installation	8977 -2	10		38		\$165	\$861	1.83	5
Boiler Replacement	115 -2	25		977		\$4,248	\$55,905	1.72	13
Burner Replacement	8874 -2	15			200	\$1,182	\$9,017	1.60	8
Turbulator Installation	7579 -2	10		33		\$144	\$861	1.59	6
Burner Replacement	7770 -2	10		345		\$1,499	\$10,319	1.38	7
Burner Replacement	7770 -1	10		344		\$1,497	\$10,319	1.38	7
Oxygen Trim System	115 -2	25		238		\$1,037	\$16,420	1.24	16
Burner Replacement	8977 -2	10		303		\$1,317	\$10,319	1.22	8
Preheat Combustion Air	115 -2	25		580		\$2,523	\$46,257	1.16	18
Steel Feedwater Economizer	115 -2	25		306		\$1,331	\$23,496	1.15	18
Burner Replacement	7579 -2	10		283		\$1,232	\$10,319	1.14	8
Steel Feedwater Economizer	7579 -1	10		607		\$2,640	\$20,862	1.12	6
Downsize Boiler	7105 -4	10		1102		\$4,792	\$40,907	1.12	9
Turbulator Installation	8028 -1	10			39	\$230	\$1,723	1.12	7
Turbulator Installation	7770 -2	10		44		\$191	\$1,723	1.06	9
Turbulator Installation	7770 -1	10		44		\$191	\$1,723	1.06	9
Boiler Tune-Up OMR	7153 -1	5		705		\$3,067	\$2,705	1.05	1
Summer Boilers	7291 -1	15		257		\$1,118	\$16,100	1.01	14
Burner Replacement	7105 -4	10		732		\$3,184	\$30,026	1.01	9
Preheat Combustion Air	8028 -2	25			522	\$3,085	\$53,996	1.00	18
Downsize Boiler	7770 -1	10		517		\$2,251	\$22,041	0.97	10
Downsize Boiler	7770 -2	10		517		\$2,251	\$22,041	0.97	10
Burner Replacement	8028 -1	10			192	\$1,134	\$10,319	0.92	9

TABLE ES 1 - BOILER ECOs EVALUATED SORTED BY SIR

ECO	Boiler No.	Life (YRS)	Elec. MBTUs	MBTUs Saved		Annual Savings	Cost Estimate	SIR	Simple Payback (Years)
				Nat. Gas MBTUs	#2 Oil MBTUs				
Steel Feedwater Economizer	7105 -3	25		254		\$1,105	\$24,773	0.88	22
Summer Boilers	7855 -1	15		347		\$1,512	\$25,478	0.86	17
Oxygen Trim System	7105 -3	25		172		\$748	\$16,420	0.84	22
Boiler Feedwater Economizer	7579 -1	10		1054		\$4,585	\$51,720	0.81	11
Turbulator Installation	7105 -2	5		34		\$148	\$862	0.78	6
Turbulator Installation	7105 -1	5		34		\$148	\$862	0.78	6
Boiler Replacement	7579 -1	10		858		\$3,734	\$45,285	0.78	12
Boiler Feedwater Economizer	115 -2	25		472		\$2,053	\$58,185	0.74	28
Boiler Tune-Up OMR	7105 -1	5		660		\$2,872	\$2,705	0.73	1
Steel Feedwater Economizer	8028 -2	25			168	\$993	\$20,862	0.73	21
Summer Boilers	7579 -1	10		441		\$1,917	\$25,478	0.72	13
Preheat Combustion Air	7579 -1	10		724		\$3,149	\$41,117	0.68	13
Burner Replacement	7153 -1	5		346		\$1,506	\$10,319	0.66	7
Boiler Feedwater Economizer	7105 -3	25		440		\$1,914	\$61,418	0.65	32
Oxygen Trim System	7579 -1	10		295		\$1,285	\$16,420	0.63	13
Summer Boilers	8874 -1	15			140	\$827	\$16,100	0.63	20
Oxygen Trim System	8874 -1	15			174	\$1,028	\$16,420	0.62	16
Preheat Combustion Air	7105 -3	25		337		\$1,466	\$48,827	0.61	33
Burner Replacement	7105 -1	5		314		\$1,365	\$10,319	0.60	8
Burner Replacement	7105 -2	5		314		\$1,365	\$10,319	0.60	8
Variable-Speed Fans	4725 -4	15	1518			\$5,644	\$86,064	0.59	15
Downsize Boiler	7105 -2	5		1177		\$5,122	\$40,907	0.57	8
Downsize Boiler	7105 -1	5		1177		\$5,122	\$40,907	0.57	8
Boiler Feedwater Economizer	8028 -2	25			365	\$2,157	\$67,883	0.54	31
Summer Boilers	7770 -1	10		238		\$1,033	\$19,226	0.51	19
Steel Feedwater Economizer	7105 -4	10		373		\$1,623	\$27,381	0.50	17
Preheat Combustion Air	8874 -1	15			265	\$1,566	\$35,978	0.46	23
Boiler Replacement	8874 -2	15			200	\$1,182	\$32,361	0.45	27
Oxygen Trim System	7105 -4	10		221		\$963	\$16,420	0.44	17
Boiler Feedwater Economizer	8874 -1	15			311	\$1,838	\$45,255	0.44	25
Steel Feedwater Economizer	8874 -1	15			137	\$810	\$18,254	0.41	23
Variable-Speed Fans	4725 -3	15	1032			\$3,837	\$86,064	0.40	22
Variable-Speed Fans	3624 -4	10	535			\$1,989	\$34,725	0.40	17
Boiler Replacement	7105 -4	10		732		\$3,184	\$77,646	0.39	24
Boiler Feedwater Economizer	7105 -4	10		645		\$2,806	\$67,883	0.37	24
Downsize Boiler	7153 -1	5		592		\$2,574	\$32,361	0.36	13
Variable-Speed Fans	3624 -2	10	470			\$1,747	\$34,725	0.35	20
Variable-Speed Fans	4725 -2	15	860			\$3,197	\$86,064	0.33	27
Steel Feedwater Economizer	8977 -1	10		212		\$922	\$20,862	0.33	23
Summer Boilers	7153 -1	5		346		\$1,506	\$22,353	0.31	15
Boiler Replacement	7770 -1	10		344		\$1,497	\$45,285	0.31	30
Boiler Replacement	7770 -2	10		344		\$1,497	\$45,285	0.31	30
Preheat Combustion Air	7105 -4	10		431		\$1,875	\$53,966	0.30	29
Oxygen Trim System	8874 -2	15			100	\$592	\$16,420	0.29	28
Boiler Feedwater Economizer	8977 -1	10		367		\$1,596	\$51,720	0.26	32
Boiler Replacement	7579 -2	10		283		\$1,232	\$45,285	0.26	37
Variable-Speed Fans	3624 -1	10	338			\$1,256	\$34,725	0.25	28
Preheat Combustion Air	8874 -2	15			152	\$898	\$35,978	0.24	40
Oxygen Trim System	8028 -1	10			115	\$682	\$16,420	0.23	24
Preheat Combustion Air	8977 -1	10		267		\$1,161	\$41,117	0.22	35
Variable-Speed Fans	3624 -3	10	299			\$1,112	\$34,725	0.22	31
Preheat Combustion Air	8028 -1	10			216	\$1,277	\$41,117	0.21	32

TABLE ES 1 - BOILER ECOs EVALUATED SORTED BY SIR

ECO	Boiler No.	Life (YRS)	Elec. MBTUs	MBTUs Saved			Annual Savings	Cost Estimate	SIR	Simple Payback (Years)
				Nat. MBTUs	Gas MBTUs	#2 Oil MBTUs				
Boiler Feedwater Economizer	8874 -2	15				168	\$993	\$45,255	0.21	46
Boiler Replacement	8028 -1	10				192	\$1,134	\$45,285	0.21	40
Oxygen Trim System	8977 -1	10		125			\$542	\$16,420	0.20	30
Boiler Replacement	8977 -1	10		749			\$3,257	\$170,520	0.18	52
Steel Feedwater Economizer	7153 -1	5		194			\$844	\$15,646	0.18	19
Steel Feedwater Economizer	7579 -2	10		133			\$579	\$20,862	0.17	36
Downsize Boiler	8977 -1	10		640			\$2,786	\$164,058	0.16	59
Steel Feedwater Economizer	8874 -2	15				74	\$437	\$18,254	0.16	42
Boiler Replacement	7153 -1	5		346			\$1,506	\$45,285	0.15	30
Boiler Feedwater Economizer	7579 -2	10		230			\$1,001	\$51,720	0.15	52
Boiler Replacement	7105 -1	5		314			\$1,365	\$45,285	0.14	33
Preheat Combustion Air	8977 -2	10		180			\$783	\$41,117	0.14	53
Boiler Replacement	7105 -2	5		314			\$1,365	\$45,285	0.14	33
Oxygen Trim System	7770 -2	10		99			\$429	\$16,420	0.14	38
Oxygen Trim System	7770 -1	10		99			\$429	\$16,420	0.14	38
Preheat Combustion Air	7153 -1	5		325			\$1,414	\$41,117	0.13	29
Oxygen Trim System	7579 -2	10		93			\$406	\$16,420	0.12	40
Oxygen Trim System	7153 -1	5		155			\$676	\$16,420	0.12	24
Boiler Feedwater Economizer	8028 -1	10				158	\$934	\$51,720	0.11	55
Boiler Feedwater Economizer	7153 -1	5		341			\$1,483	\$51,720	0.11	35
Preheat Combustion Air	7770 -1	10		179			\$779	\$51,396	0.11	66
Preheat Combustion Air	7770 -2	10		179			\$779	\$51,396	0.11	66
Preheat Combustion Air	7579 -2	10		145			\$631	\$41,117	0.10	65
Oxygen Trim System	8977 -2	10		83			\$363	\$16,420	0.10	45
Downsize Boiler	8977 -2	10		361			\$1,569	\$164,058	0.09	105
Steel Feedwater Economizer	8028 -1	10				82	\$485	\$27,381	0.08	57
Steel Feedwater Economizer	7770 -2	10		90			\$392	\$26,077	0.07	67
Boiler Feedwater Economizer	7770 -2	10		158			\$687	\$64,650	0.07	94
Steel Feedwater Economizer	7770 -1	10		90			\$392	\$26,077	0.07	67
Boiler Replacement	8977 -2	10		303			\$1,317	\$170,520	0.07	130
Boiler Feedwater Economizer	7770 -1	10		158			\$687	\$64,650	0.07	94
Boiler Feedwater Economizer	7105 -2	5		184			\$800	\$51,720	0.05	64
Boiler Feedwater Economizer	7105 -1	5		183			\$796	\$51,720	0.05	65
Variable-Speed Fans	4725 -1	15	138				\$513	\$86,064	0.05	168
Steel Feedwater Economizer	7105 -1	5		105			\$457	\$20,862	0.05	46
Steel Feedwater Economizer	7105 -2	5		106			\$461	\$20,862	0.05	45
Preheat Combustion Air	7105 -1	5		141			\$613	\$41,117	0.04	67
Preheat Combustion Air	7105 -2	5		141			\$613	\$41,117	0.04	67
Oxygen Trim System	7105 -1	5		76			\$329	\$16,420	0.03	50
Oxygen Trim System	7105 -2	5		76			\$329	\$16,420	0.03	50
Boiler Tune-Up OMR	8874 -1	15				33	\$197	\$2,705	-8.20	14
Boiler Tune-Up OMR	7105 -3	25		102			\$443	\$2,705	-7.91	6
Boiler Tune-Up OMR	8977 -2	10		45			\$196	\$2,705	-6.31	14
Boiler Tune-Up OMR	8028 -1	10				151	\$895	\$2,705	-5.51	3
Boiler Tune-Up OMR	7579 -2	10		103			\$448	\$2,705	-5.42	6
Boiler Tune-Up OMR	8874 -2	15				245	\$1,447	\$2,705	-2.54	2
Boiler Tune-Up OMR	7770 -2	10		307			\$1,336	\$2,705	-2.30	2
Boiler Tune-Up OMR	7105 -2	5		288			\$1,252	\$2,705	-1.99	2

TABLE ES 2 - CHILLER EOs SORTED BY SIR

ECO's PERFORMED	TONS	Chiller No.	Life (Yrs)	Elec. MBIUs	Annual Savings	Cost Estimate	SIR	Simple Payback (Years)
CHILLER SHUTDOWN	440	4488-2	15	12396	\$46,088	\$1,496	277.22	0.03
CHILLER SHUTDOWN	373	5250-1	10	15600	\$58,001	\$1,496	271.61	0.03
CHILLER SHUTDOWN	160	7120-1	20	5170	\$19,222	\$1,496	133.29	0.08
CHILLER SHUTDOWN	200	4484-1	10	3206	\$11,920	\$1,496	71.70	0.13
CHILLER SHUTDOWN	225	3220-1	10	3961	\$14,727	\$1,496	68.96	0.10
CHILLED WATER TEMPERATURE RESET	660	5400-1	20	343	\$1,276	\$329	40.21	0.3
CHILLED WATER TEMPERATURE RESET	670	3305-1	10	229	\$850	\$329	18.13	0.4
CHILLED WATER TEMPERATURE RESET	440	4488-2	15	162	\$603	\$329	16.47	0.5
CHILLED WATER TEMPERATURE RESET	225	3220-1	10	135	\$503	\$329	10.70	0.7
CHILLED WATER TEMPERATURE RESET	250	5681-2	10	133	\$496	\$329	10.53	0.7
CHILLED WATER TEMPERATURE RESET	373	5250-2	5	132	\$492	\$329	10.45	0.7
CHILLED WATER TEMPERATURE RESET	373	5250-1	10	132	\$492	\$329	10.45	0.7
CHILLED WATER TEMPERATURE RESET	200	4484-1	10	81	\$301	\$329	8.24	1.1
CHILLED WATER TEMPERATURE RESET	160	7120-1	20	68	\$254	\$329	7.97	1.3
CHILLED WATER TEMPERATURE RESET	155	5681-1	10	83	\$307	\$329	6.57	1.1
CHILLED WATER TEMPERATURE RESET	180	7770-1	10	70	\$262	\$329	5.54	1.3
CHILLED WATER TEMPERATURE RESET	155	5681-3	10	55	\$205	\$329	4.35	1.6
WATERSIDE ECONOMIZER	247	4500-1	20	2953	\$10,979	\$31,696	3.59	2.9
WATERSIDE ECONOMIZER	660	5400-1	20	3215	\$11,953	\$81,131	1.53	6.8
TWO SPEED COOLING TOWER FAN - 2	200	3485-1	20	110	\$410	\$3,156	1.35	7.7
TWO SPEED COOLING TOWER FAN - 2	130	109-1	15	110	\$410	\$3,156	1.17	7.7
WATERSIDE ECONOMIZER	180	7770-1	10	1247	\$4,637	\$30,408	1.07	6.6
TWO SPEED COOLING TOWER FAN - 2	225	3220-1	10	110	\$410	\$3,156	0.91	7.7
VARIABLE SPEED PUMPING	225	3220-1	10	874	\$3,250	\$44,612	0.69	13.7
TWO SPEED COOLING TOWER FAN - 2	180	7770-1	10	74	\$273	\$2,800	0.68	10.3
WATERSIDE ECONOMIZER	670	3305-1	10	1895	\$7,046	\$74,707	0.66	10.6
WATERSIDE ECONOMIZER	204	4505-1	10	813	\$3,022	\$33,132	0.64	11.0
VARIABLE SPEED PUMPING	200	3485-1	20	586	\$2,178	\$32,462	0.64	14.9
VARIABLE SPEED PUMPING	155	5681-1	10	1904	\$7,080	\$118,325	0.57	16.7
TWO SPEED COOLING TOWER FAN - 1	200	3485-1	20	42	\$157	\$3,156	0.52	20.1
TWO SPEED COOLING TOWER FAN - 1	130	109-1	15	42	\$157	\$3,156	0.45	20.1
TWO SPEED COOLING TOWER FAN - 2	247	4500-1	20	37	\$137	\$3,156	0.45	23.1
WATERSIDE ECONOMIZER	440	4488-1	10	725	\$2,696	\$56,074	0.43	20.8
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	660	5400-1	20	369	\$1,373	\$25,092	0.42	18.3
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	660	5400-2	20	369	\$1,373	\$25,092	0.42	18.3
WATERSIDE ECONOMIZER	160	7120-1	20	297	\$1,104	\$30,408	0.38	27.5
TWO SPEED COOLING TOWER FAN - 1	225	3220-1	10	42	\$157	\$3,156	0.35	20.1
TWO SPEED COOLING TOWER FAN - 2	204	4505-1	10	37	\$137	\$2,800	0.34	20.4
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	670	3305-2	10	370	\$1,376	\$25,463	0.32	18.5
VARIABLE SPEED PUMPING	200	4484-1	10	274	\$1,020	\$31,133	0.31	30.5
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	670	3305-1	10	370	\$1,376	\$25,463	0.29	18.5
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	200	3485-1	20	131	\$487	\$13,789	0.27	28.3
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	160	7120-1	20	110	\$411	\$11,709	0.26	28.5
TWO SPEED COOLING TOWER FAN - 1	180	7770-1	10	28	\$105	\$2,800	0.26	26.7
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	200	4484-1	10	131	\$487	\$13,789	0.23	28.3
WATERSIDE ECONOMIZER	130	109-1	15	212	\$786	\$30,408	0.23	38.7
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	247	4500-1	20	138	\$513	\$16,336	0.22	31.8
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	130	109-1	15	85	\$316	\$9,514	0.21	30.1
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	373	5250-1	10	214	\$796	\$21,006	0.20	26.4
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	373	5250-2	5	214	\$796	\$21,006	0.20	26.4
WATERSIDE ECONOMIZER	200	3485-1	20	154	\$571	\$31,856	0.19	55.8
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	225	3220-1	10	146	\$541	\$14,881	0.19	27.5
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	180	7770-1	10	114	\$424	\$13,173	0.17	31.1
TWO SPEED COOLING TOWER FAN - 1	247	4500-1	20	14	\$52	\$3,156	0.17	60.4

TABLE ES 2 - CHILLER ECOS SORTED BY SIR

ECO's PERFORMED	TONS	Chiller No.	Life (Yrs)	Elec. MBTUs	Annual Savings	Cost Estimate	SIR	Simple Payback (Years)
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	204	4505-1	10	117	\$435	\$13,777	0.16	31.7
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	155	5681-1	10	89	\$331	\$11,343	0.15	34.3
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	155	5681-3	10	89	\$331	\$10,906	0.15	32.9
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	250	5681-2	10	144	\$534	\$16,531	0.14	31.0
TWO SPEED COOLING TOWER FAN - 1	204	4505-1	10	14	\$52	\$2,800	0.13	53.8
WATERSIDE ECONOMIZER	225	3220-1	10	142	\$528	\$32,011	0.12	60.6
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	200	5400-3	5	115	\$427	\$13,789	0.11	32.3
CENTRIFUGAL CHILLER REPLACEMENT	373	5250-2	5	405	\$1,506	\$113,074	0.05	75.1
WATERSIDE ECONOMIZER	373	5250-1	10	77	\$286	\$49,612	0.04	173.5
WATER TREATMENT / FILL REPLACEMENT	130	109-1	15	24	\$88	\$14,150	-1.73	160.8
CONDENSER TUBE CLEANING	373	5250-2	5	428	\$1,591	\$5,412	-2.87	3.4
CONDENSER TUBE CLEANING	200	5400-3	5	230	\$855	\$2,902	-2.87	3.4
WATER TREATMENT / FILL REPLACEMENT	180	7770-1	10	35	\$131	\$8,782	-2.99	67.0
WATER TREATMENT / FILL REPLACEMENT	204	4505-1	10	36	\$134	\$9,765	-3.06	72.9
WATER TREATMENT / FILL REPLACEMENT	225	3220-1	10	45	\$167	\$10,263	-3.20	61.5
WATER TREATMENT / FILL REPLACEMENT	440	4488-1	10	78	\$290	\$18,380	-3.51	63.4
WATER TREATMENT / FILL REPLACEMENT	373	5250-1	10	66	\$245	\$15,153	-3.60	61.8
WATER TREATMENT / FILL REPLACEMENT	670	3305-1	10	114	\$425	\$24,957	-3.94	58.7
WATER TREATMENT / FILL REPLACEMENT	670	3305-2	10	114	\$425	\$24,957	-3.94	58.7
WATER TREATMENT / FILL REPLACEMENT	247	4500-1	20	44	\$163	\$13,796	-3.96	84.6
WATER TREATMENT / FILL REPLACEMENT	160	7120-1	20	34	\$126	\$8,307	-4.23	65.9
WATER TREATMENT / FILL REPLACEMENT	440	4488-2	15	81	\$301	\$18,380	-4.55	61.1
CONDENSER TUBE CLEANING	225	3220-1	10	291	\$1,082	\$3,265	-4.67	3.0
CONDENSER TUBE CLEANING	180	7770-1	10	228	\$848	\$2,612	-4.72	3.1
CONDENSER TUBE CLEANING	155	5681-1	10	178	\$662	\$2,249	-4.93	3.4
CONDENSER TUBE CLEANING	250	5681-2	10	287	\$1,067	\$3,627	-4.93	3.4
CONDENSER TUBE CLEANING	155	5681-3	10	178	\$662	\$2,249	-4.93	3.4
CONDENSER TUBE CLEANING	440	4488-1	10	505	\$1,878	\$6,384	-4.94	3.4
CONDENSER TUBE CLEANING	373	5250-1	10	428	\$1,591	\$5,412	-4.94	3.4
CONDENSER TUBE CLEANING	204	4505-1	10	234	\$870	\$2,960	-4.94	3.4
CONDENSER TUBE CLEANING	670	3305-2	10	740	\$2,751	\$9,721	-5.01	3.5
CONDENSER TUBE CLEANING	670	3305-1	10	740	\$2,751	\$9,721	-5.01	3.5
WATER TREATMENT / FILL REPLACEMENT	200	3485-1	20	40	\$149	\$8,259	-5.33	55.4
WATER TREATMENT / FILL REPLACEMENT	660	5400-1	20	114	\$424	\$24,719	-5.91	58.3
WATER TREATMENT / FILL REPLACEMENT	660	5400-2	20	114	\$424	\$24,676	-5.92	58.2
CONDENSER TUBE CLEANING	200	4484-1	10	262	\$974	\$2,902	-6.06	3.0
CONDENSER TUBE CLEANING	440	4488-2	15	524	\$1,948	\$6,384	-6.33	3.3
CONDENSER TUBE CLEANING	130	109-1	15	153	\$569	\$1,886	-6.36	3.3
CONDENSER TUBE CLEANING	160	7120-1	20	221	\$822	\$2,322	-6.88	2.8
CONDENSER TUBE CLEANING	200	3485-1	20	262	\$974	\$2,902	-7.07	3.0
CONDENSER TUBE CLEANING	247	4500-1	20	276	\$1,026	\$3,584	-7.58	3.5
CONDENSER TUBE CLEANING	660	5400-1	20	739	\$2,748	\$9,576	-7.58	3.5
CONDENSER TUBE CLEANING	660	5400-2	20	737	\$2,740	\$9,576	-7.58	3.5
STM DRIVEN VS. ELEC. DRIVEN CHILLERS	225	3220-1	10	4650	\$2,028	\$188,975	NA	93.2

EOO	MBTUs Saved					Annual Savings	Cost Estimate	SIR	Simple Payback (Years)
	Boiler No.	Economic life	Elec. MBTUs	Nat. Gas MBTUs	#2 Oil MBTUs				
* Boiler Tune-Up OMR	115-2	25		903		\$3,927	\$2,705	21.18	0.69
Turbulator Installation	115-2	25		120		\$522	\$1,295	9.10	2.50
** Burner Replacement	115-2	25		977		\$4,248	\$11,622	8.26	2.70
** Boiler Downsizing	115-2	25		1488		\$6,475	\$45,285	3.23	7.00
Steel Economizer	115-2	25		306		\$1,333	\$23,496	1.15	18.00
Summer Boiler	115-2	25		559		\$2,430	\$25,478	2.16	10.50
** Boiler Replacement	115-2	25		977		\$4,248	\$55,905	1.72	13.20
Oxygen Trim System	115-2	25		238		\$1,037	\$16,420	1.24	16.00
Preheat Combustion Air	115-2	25		580		\$2,523	\$46,257	1.16	18.00
* Boiler Tune-Up OMR	3624-1	10		2449		\$10,655	\$2,705	30.48	0.25
* Boiler Tune-Up OMR	3624-2	10		748		\$3,254	\$2,705	4.45	0.83
* Boiler Tune-Up OMR	3624-3	10		8599		\$37,407	\$2,705	124.60	0.07
* Boiler Tune-Up OMR	3624-4	10		34338		\$149,372	\$2,705	518.52	0.02
* Boiler Tune-Up OMR	4725-1	15		1945		\$8,460	\$2,705	36.27	0.32
* Boiler Tune-Up OMR	4725-2	15		21293		\$92,626	\$2,705	495.49	0.03
* Boiler Tune-Up OMR	4725-3	15		57931		\$251,998	\$2,705	1341.68	0.01
Turbulator Installation	7105-3	25		69		\$300	\$1,723	3.93	5.70
Burner Replacement	7105-3	25		413		\$1,795	\$13,575	2.99	7.60
Boiler Downsizing	7105-3	25		774		\$3,368	\$40,907	1.86	12.10
*** Boiler Tune-Up OMR	7105-4	10		925		\$4,025	\$2,705	7.16	0.67
*** Turbulator Installation	7105-4	10		86		\$374	\$1,723	2.07	4.60
*** Boiler Downsizing	7105-4	10		1102		\$4,792	\$40,907	1.12	8.50
*** Burner Replacement	7105-4	10		732		\$3,184	\$30,026	1.01	9.40
Turbulator Installation	7153-1	5		82		\$357	\$287	5.64	0.80
* Boiler Tune-Up OMR	7153-1	5		705		\$3,067	\$2,705	1.05	0.88
Summer Boiler	7291-1	15		257		\$1,118	\$16,100	1.01	14.40
Turbulator Installation	7579-1	10		156		\$679	\$861	7.50	1.27
Burner Replacement	7579-1	10		858		\$3,734	\$10,319	3.44	2.80
Steel Economizer	7579-1	10		607		\$2,640	\$20,862	1.12	6.00
Turbulator Installation	7579-2	10		33		\$144	\$861	1.59	6.00
Burner Replacement	7579-2	10		283		\$1,232	\$10,319	1.14	8.40
**** Burner Replacement	7770-1	10		344		\$1,497	\$10,319	1.38	6.90
Turbulator Installation	7770-1	10		44		\$191	\$1,723	1.06	9.00
**** Burner Replacement	7770-2	10		345		\$1,499	\$10,319	1.38	6.90
Turbulator Installation	7770-2	10		44		\$191	\$1,723	1.06	9.00
Turbulator Installation	8028-1	10			39	\$230	\$1,723	1.12	7.48
* Boiler Tune-Up OMR	8028-2	25			529	\$3,125	\$2,705	19.21	0.87
Turbulator Installation	8028-2	25			98	\$579	\$1,723	6.21	2.98
Oxygen Trim System	8028-2	25			279	\$1,649	\$16,420	1.67	9.96
Preheat Combustion Air	8028-2	25			522	\$3,085	\$53,996	1.00	18.00
Turbulator Installation	8874-1	15			49	\$290	\$518	6.82	1.79
Burner Replacement	8874-1	15			319	\$1,882	\$9,017	2.55	4.80
Turbulator Installation	8874-2	15			28	\$165	\$518	3.90	3.13
Burner Replacement	8874-2	15			200	\$1,182	\$9,017	1.60	7.60
* Boiler Tune-Up OMR	8977-1	10		1965		\$8,548	\$2,705	23.08	0.32
Burner Replacement	8977-1	10		749		\$3,257	\$10,319	3.00	3.20
Turbulator Installation	8977-1	10		52		\$226	\$861	2.50	3.81
Turbulator Installation	8977-2	10		38		\$165	\$861	1.83	5.21
Burner Replacement	8977-2	10		303		\$1,317	\$10,319	1.22	7.80

* Package in place (work to be completed in summer 1987) } Per guidance through letter dated May 18, 1987,
 ** Work completed } from Keith Kirkly for Paul W. Hancock, Director
 *** Discontinued - new system in place } of Engineering and Housing, to Norm Meinert of
 **** Boiler rehabilitation package # 1 (work in progress) } Benatech, Inc.

TABLE ES 4 - CHILLER ECOs WITH SIR > 1 (SORTED BY BUILDING)

ECO's PERFORMED	Chiller TONS	Life No.	Elec. Life (YRS.)	MEtUs Savings	Annual Savings	Cost Estimate	SIR	Simple Payback (Years)
TWO SPEED COOLING TOWER FAN - 2	130	109-1	15	110	\$410	\$3,156	1.17	7.70
CHILLER SHUTDOWN	225	3220-1	10	3961	\$14,727	\$1,496	68.96	0.10
CHILLED WATER TEMPERATURE RESET	225	3220-1	10	135	\$503	\$329	10.70	0.65
* CHILLED WATER TEMPERATURE RESET	670	3305-1	10	229	\$850	\$329	18.13	0.39
TWO SPEED COOLING TOWER FAN - 2	200	3485-1	20	110	\$410	\$3,156	1.35	7.70
CHILLER SHUTDOWN	200	4484-1	10	3206	\$11,920	\$1,496	71.70	0.13
CHILLED WATER TEMPERATURE RESET	200	4484-1	10	81	\$301	\$329	8.24	1.09
CHILLER SHUTDOWN	440	4488-2	15	12396	\$46,088	\$1,496	277.22	0.03
* CHILLED WATER TEMPERATURE RESET	440	4488-2	15	162	\$603	\$329	16.47	0.55
WATERSIDE ECONOMIZER	247	4500-1	20	2953	\$10,979	\$31,696	3.59	2.89
CHILLER SHUTDOWN	373	5250-1	10	15600	\$58,001	\$1,496	271.61	0.03
* CHILLED WATER TEMPERATURE RESET	373	5250-1	10	132	\$492	\$329	10.45	0.67
* CHILLED WATER TEMPERATURE RESET	373	5250-2	5	132	\$492	\$329	10.45	0.67
CHILLED WATER TEMPERATURE RESET	660	5400-1	20	343	\$1,276	\$329	40.21	0.26
WATERSIDE ECONOMIZER	660	5400-1	20	3215	\$11,953	\$81,131	1.53	6.79
CHILLED WATER TEMPERATURE RESET	155	5681-1	10	83	\$307	\$329	6.57	1.07
CHILLED WATER TEMPERATURE RESET	250	5681-2	10	133	\$496	\$329	10.53	0.66
CHILLED WATER TEMPERATURE RESET	155	5681-3	10	55	\$205	\$329	4.35	1.60
CHILLER SHUTDOWN	160	7120-1	20	5170	\$19,222	\$1,496	133.29	0.08
CHILLED WATER TEMPERATURE RESET	160	7120-1	20	68	\$254	\$329	7.97	1.30
CHILLED WATER TEMPERATURE RESET	180	7770-1	10	70	\$262	\$329	5.54	1.26
WATERSIDE ECONOMIZER	180	7770-1	10	1247	\$4,637	\$30,408	1.07	6.56

* Work to be accomplished in FY88 per guidance of letter dated May 13, 1987, from Keith Kirkley for Paul W. Hancock, Director of Engineering and Housing, to Norm Meinert of Benatech, Inc.

3.3 RECOMMENDATIONS

Once all the ECOs which offered project potential were isolated, the synergistic effects of each combination were evaluated. The results of the iterative analysis are the No cost/Low Cost Projects. There are four projects as described below.

1. Boiler Optimization

- These projects are on a per-boiler basis. They include all ECOs per respective boiler, with SIRs greater than 1.0, that are not already being implemented and are not mutually exclusive with other ECOs for the same boiler.

2. Chiller Optimization

- These projects are on a per-chiller basis and include ECOs for the respective chiller with SIRs greater than 1.0. ECOs included in optimization projects are chilled water reset and chiller shutdown if they already are not implemented. The term optimization describes chiller operation and obtaining the appropriate amount of refrigeration affect when it is necessary.

3. Chiller Economizer

- These projects are on a per-chiller basis and include ECOs for the respective chiller with SIRs greater than 1.0. ECOs included in optimization projects are water side economizer and two-speed cooling tower unless they have already been implemented. The term economizer refers to the condenser water side of the chilled water system.

4. Complete Chiller Optimization

- These projects are on a per-chiller basis and include ECOs for the respective chiller with SIRs greater than 1.0. ECOs included in complete optimization projects include chilled water reset, condenser tube cleaning, automatic chiller tube cleaner, water treatment/fill replacement, water side economizer, variable speed pumping, two-speed cooling tower and chiller shutdown. The term economizer refers to all projects which will enhance the performance of the chiller.

The results of the Boiler and Chiller study are shown in Table ES 5. Table ES 6 is a summary of boiler projects by type of project. Table ES 7 is a summary of chiller projects sorted by building number. Graphs ES 1 and ES 2 depict current boiler plant fuel consumption compared with the reduced energy consumption should all boiler projects be implemented. Graphs ES 3 through ES 5 show the energy savings from the Chiller Projects, broken down by type and by building number. Graph ES 6, shows energy savings by fuel type for both Boiler and Chiller Projects.

TABLE ES 5 - SUMMARY OF PROJECTS

	ANNUAL SAVINGS			Annual	Cost	Simple
	ELECTRIC	NAT GAS	#2 OIL	Annual	Estimate	Payback
	(MBTUs)	(MBTUs)	(MBTUs)	\$\$		(Years)
BOILER TOTALS	0	4,821	1,636	\$30,636	\$231,957	7.57
CHILLER TOTALS	48,820	0	0	\$181,178	\$159,659	0.88
STUDY TOTALS	48,820	4,821	1,636	\$211,814	\$391,616	1.85

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TOTAL MBTUs/YR: 55,277

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TABLE ES 6 - SUMMARY OF BOILER PROJECTS BY BUILDING

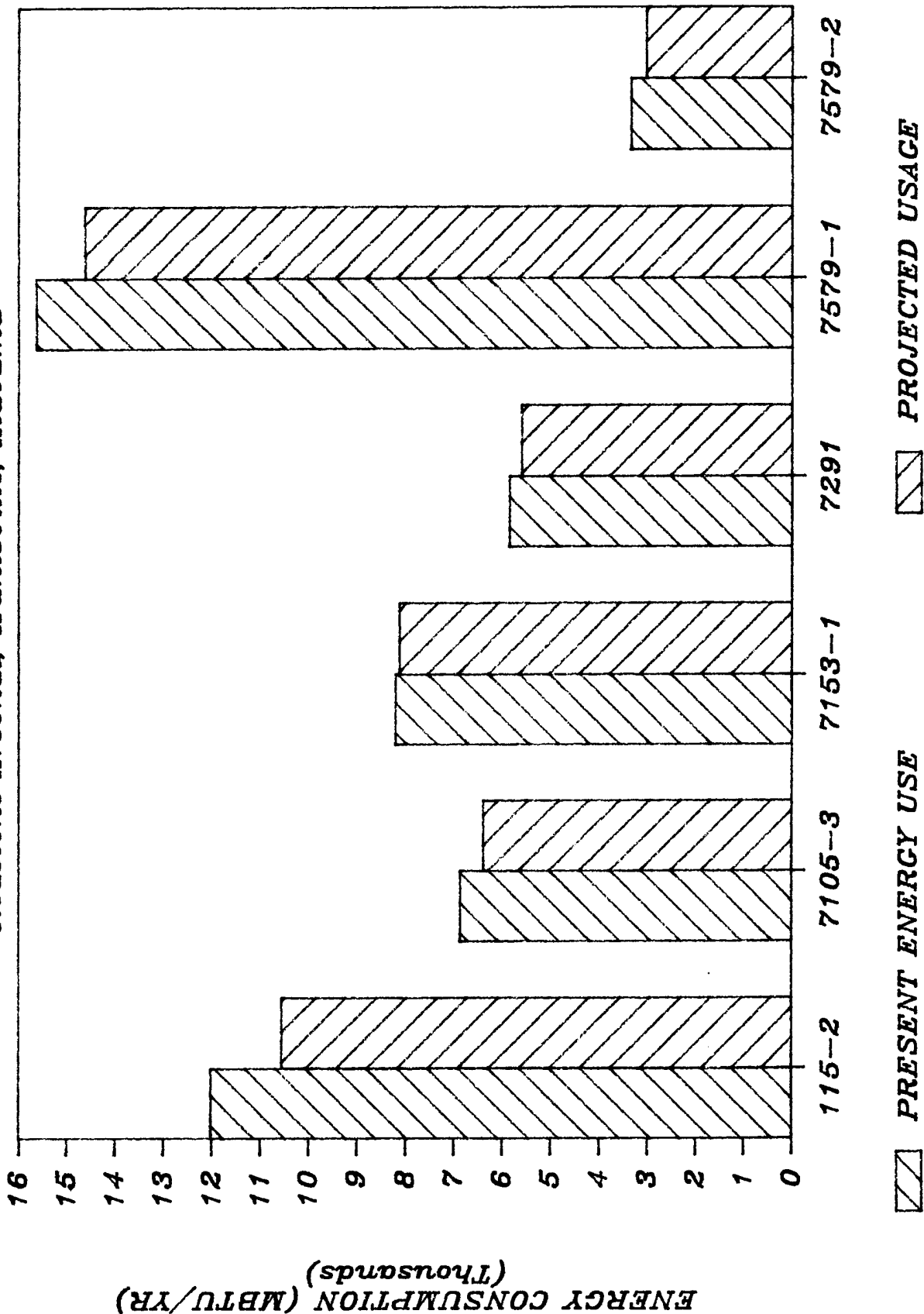
PROJECT TITLE	Boiler No.	Life (YRS)	SAVINGS		Annual Savings	Cost Estimate	SIR	Simple Payback (Years)
			NAT GAS (MBTUs)	#2 OIL (MBTUs)				
BOILER OPTIMIZATION	115-2	25	1466		\$6,375	\$59,174	2.38	9.28
BOILER OPTIMIZATION	7105-3	25	477		\$2,076	\$15,298	3.06	7.37
BOILER OPTIMIZATION	7153-1	5	82		\$357	\$287	5.65	0.80
BOILER OPTIMIZATION	7291	15	257		\$1,118	\$16,100	1.01	14.40
BOILER OPTIMIZATION	7579-1	10	1006		\$4,377	\$11,180	3.73	2.55
BOILER OPTIMIZATION	7579-2	10	314		\$1,365	\$11,180	1.16	8.19
BOILER OPTIMIZATION	7770-1	10	44		\$190	\$1,723	1.05	9.07
BOILER OPTIMIZATION	7770-2	10	44		\$190	\$1,723	1.05	9.07
BOILER OPTIMIZATION	8028-1	10		39	\$232	\$1,723	1.12	7.43
BOILER OPTIMIZATION	8028-2	25		1006	\$5,947	\$72,139	1.44	12.13
BOILER OPTIMIZATION	8874-1	15		365	\$2,154	\$9,535	2.76	4.43
BOILER OPTIMIZATION	8874-2	15		226	\$1,336	\$9,535	1.71	7.14
BOILER OPTIMIZATION	8897-1	10	794		\$3,452	\$11,180	2.94	3.24
BOILER OPTIMIZATION	8897-2	10	337		\$1,467	\$11,180	1.25	7.62
TOTALS:			4821	1636	\$30,636	\$231,957		7.57
			=====	=====	=====	=====		===

TABLE ES 7 - SUMMARY OF CHILLER PROJECTS BY BUILDING

PROJECT TITLE	TONS	Chiller No.	Life (YRS)	Elec. METUs Savings	Annual Savings	Cost Estimate	SIR	Simple Payback (Years)
CHILLER ECONOMIZER	130	109-1	15	110	\$409	\$3,156	1.17	7.72
CHILLER OPTIMIZATION	225	3220-1	10	4096	\$15,229	\$1,825	58.46	0.12
CHILLER ECONOMIZER	200	3485-1	20	110	\$410	\$3,156	1.35	7.70
CHILLER OPTIMIZATION	200	4484-1	10	3287	\$12,221	\$1,825	60.26	0.15
CHILLER OPTIMIZATION	440	4488-2	15	12396	\$46,088	\$1,496	277.22	0.03
CHILLER ECONOMIZER	247	4500-1	20	2953	\$10,979	\$31,696	3.59	2.89
CHILLER OPTIMIZATION	373	5250-1	10	15600	\$58,001	\$1,496	271.61	0.03
COMPLETE CHILLER OPTIMIZATION	660	5400-1	20	3387	\$12,593	\$81,460	1.60	6.47
CHILLER OPTIMIZATION	155	5681-1	10	83	\$309	\$329	6.57	1.06
CHILLER OPTIMIZATION	250	5681-2	10	133	\$494	\$329	10.53	0.67
CHILLER OPTIMIZATION	155	5681-3	10	55	\$204	\$329	4.35	1.61
CHILLER OPTIMIZATION	160	7120-1	20	5328	\$19,475	\$1,825	110.70	0.09
COMPLETE CHILLER OPTIMIZATION	180	7770-1	10	1282	\$4,766	\$30,737	1.09	6.45
TOTALS:				48820	\$181,178	\$159,659		0.88
				=====	=====	=====		===

BOILER PROJECTS — ENERGY SAVINGS

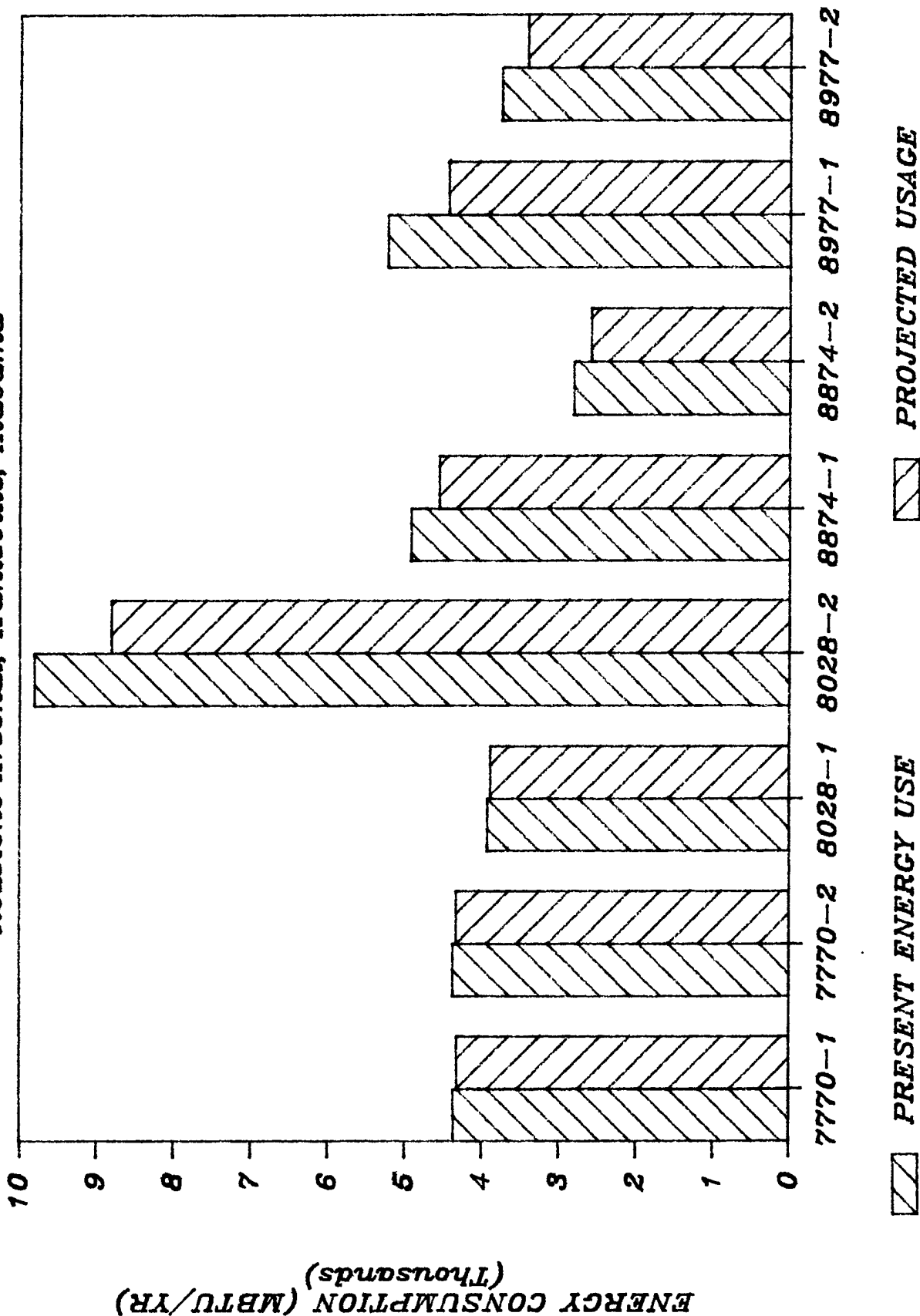
Redstone Arsenal, Huntsville, Alabama



GRAPH ES 2 BOILER SAVINGS BY BUILDING

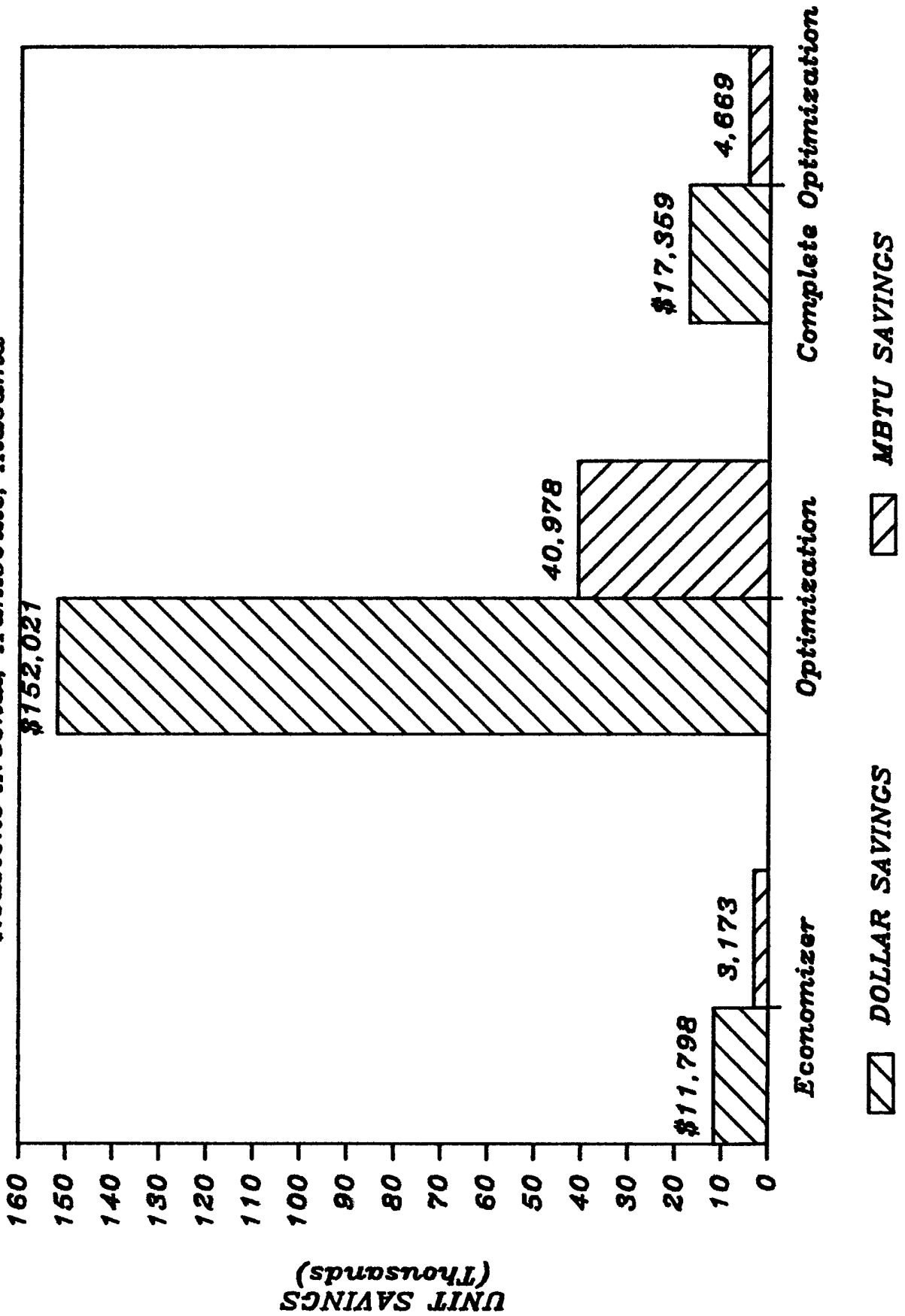
BOILER PROJECTS — ENERGY SAVINGS

Redstone Arsenal, Huntsville, Alabama



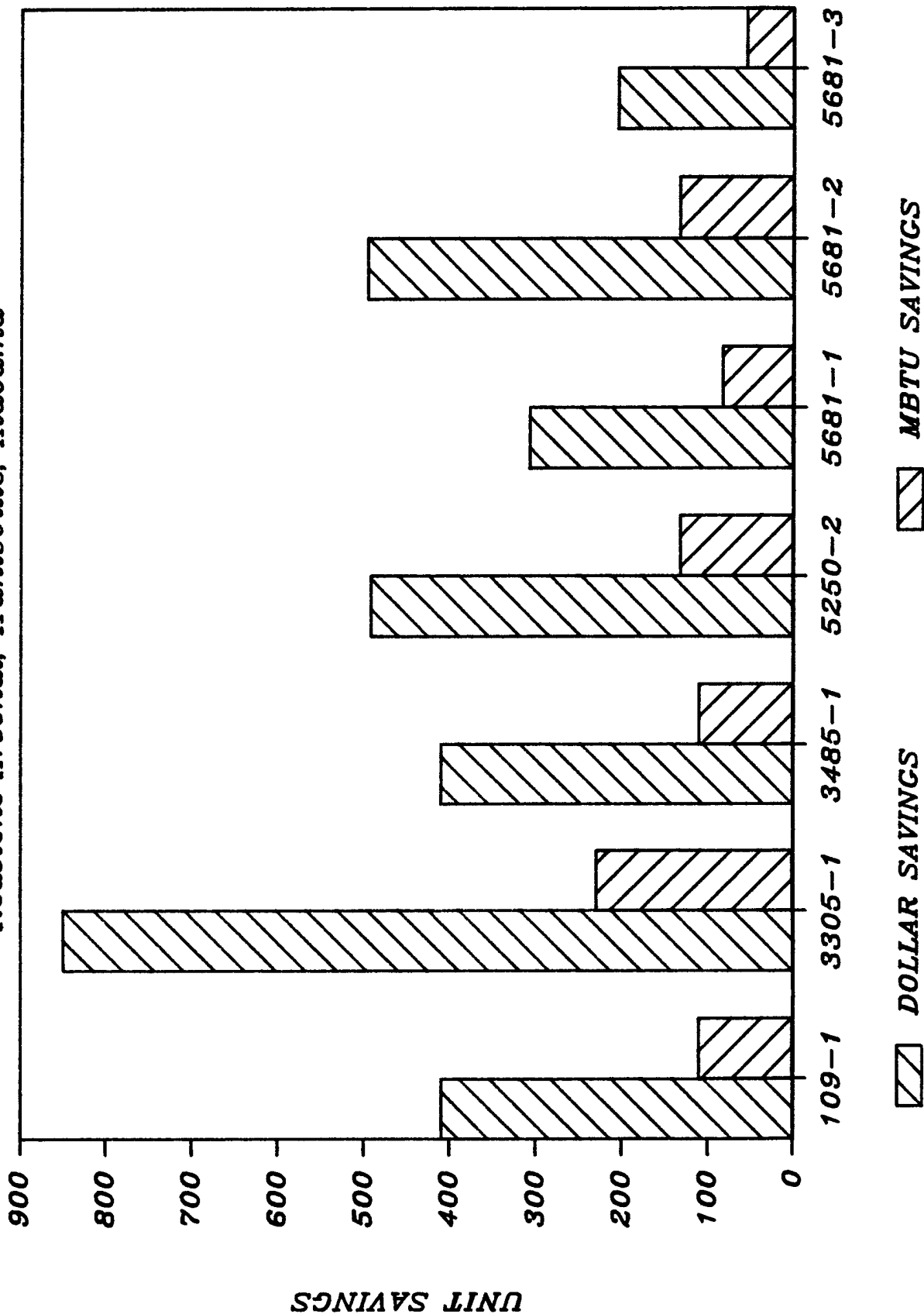
CHILLER PROJECTS SAVINGS

Redstone Arsenal, Huntsville, Alabama



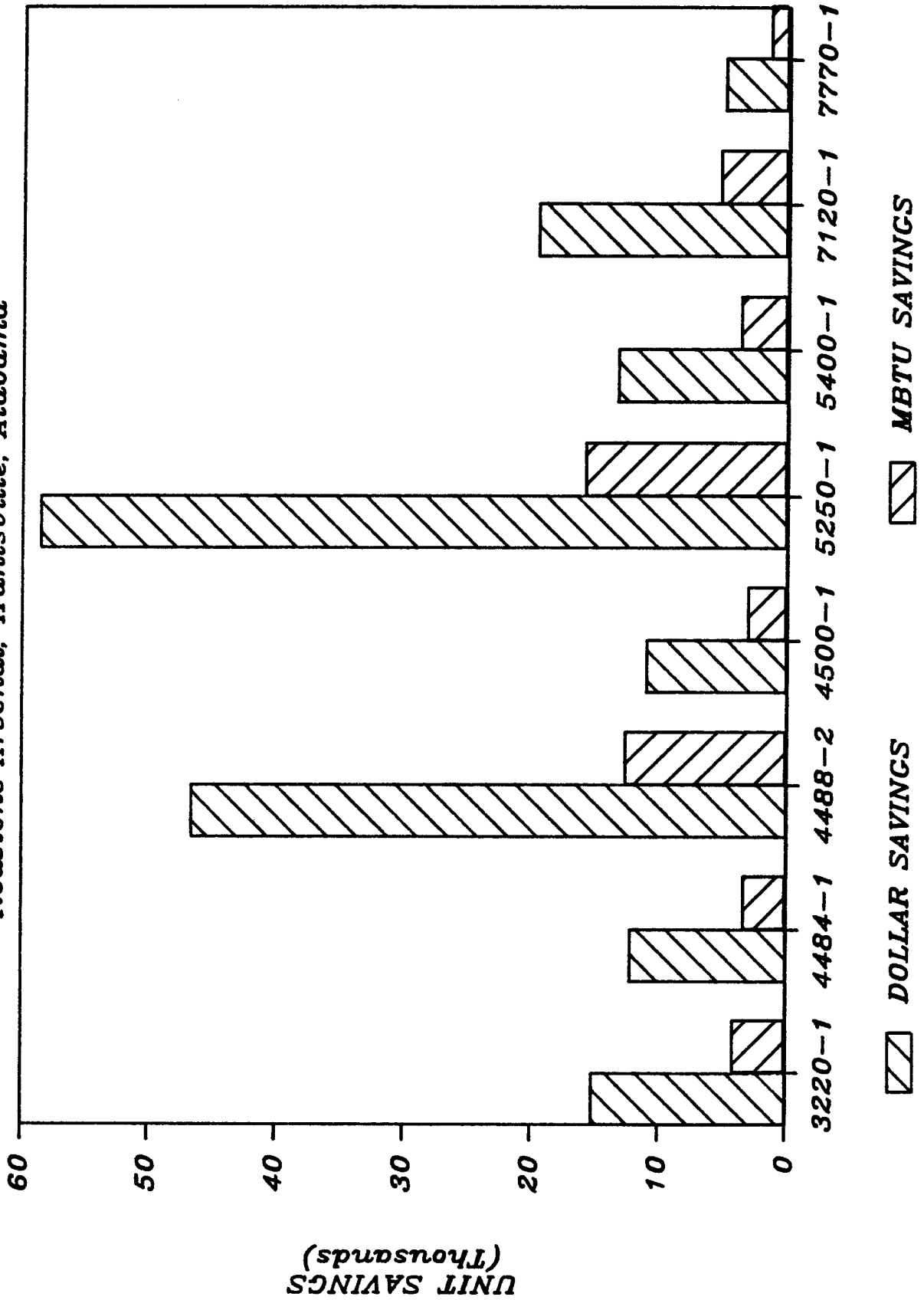
CHILLER PROJECTS SAVINGS

Redstone Arsenal, Huntsville, Alabama



CHILLER PROJECTS SAVINGS

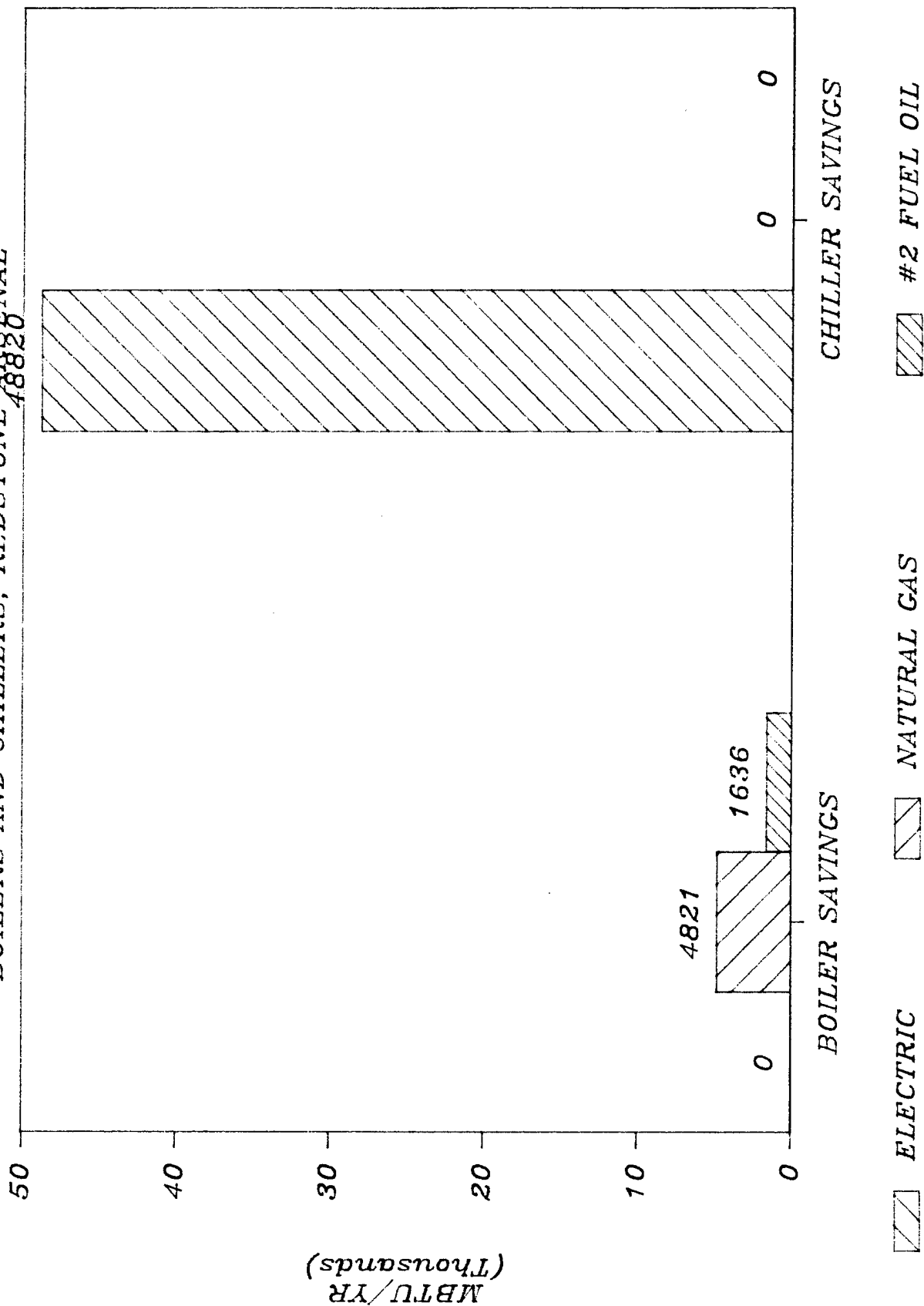
Redstone Arsenal, Huntsville, Alabama



GRAPH ES 6 ENERGY SAVINGS BY FUEL TYPE

ENERGY SAVINGS BY FUEL TYPE

BOILERS AND CHILLERS, REDSTONE ARSENAL



I N D E X

ECO Title	B/C #	Vol #	App	ECO Page	RESULTS Page	COST EST Page	ECIP Page	TEST Page	TABLE Page
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	109	1	VIII - D	83,84	82	85,86	87		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	3220	1	VIII - D	88,89	82	90,91	92		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	3305	2	VIII - D	98,99	82	100,101	102		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	3305	1	VIII - D	93,94	82	95,96	97		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	3485	1	VIII - D	103,104	82	105,106	107		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	4484	1	VIII - D	108,109	82	110,111	112		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	4500	1	VIII - D	113,114	82	115,116	117		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	4505	1	VIII - D	118,119	82	120,121	122		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	5250	1	VIII - D	123,124	82	125,126	127		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	5250	2	VIII - D	128,129	82	130,131	132		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	5400	2	VIII - D	138,139	82	140,141	142		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	5400	1	VIII - D	133,134	82	135,136	137		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	5400	3	VIII - D	143,144	82	145,146	147		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	5681	1	VIII - D	148,149	82	150,151	152		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	5681	2	VIII - D	153,154	82	155,156	157		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	5681	3	VIII - D	158,159	82	160,161	162		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	7120	1	VIII - D	163,164	82	165,166	167		
AUTOMATIC CHILLER TUBE CLEANING SYSTEM	7770	1	VIII - D	168,169	82	170,171	172		
BACKGROUND	Ex	I	-	1					
BOILER AND CHILLER CONTROL SYSTEMS	N	II	- 3	4					
BOILER AND CHILLER OPERATION AND MAINTENANCE	N	II	- 3	4					
BOILER FEEDWATER ECONOMIZER	115	2	VI - C	460-462	458	463	464		459
BOILER FEEDWATER ECONOMIZER	7105	1	VI - C	465-467	458	468	469		459
BOILER FEEDWATER ECONOMIZER	7105	4	VI - C	480-482	458	483	484		459
BOILER FEEDWATER ECONOMIZER	7105	3	VI - C	475-477	458	478	479		459
BOILER FEEDWATER ECONOMIZER	7105	2	VI - C	470-472	458	473	474		459
BOILER FEEDWATER ECONOMIZER	7153	1	VI - C	485-487	458	488	489		459
BOILER FEEDWATER ECONOMIZER	7579	2	VI - C	495-497	458	498	499		459
BOILER FEEDWATER ECONOMIZER	7579	1	VI - C	490-492	458	493	494		459
BOILER FEEDWATER ECONOMIZER	7770	2	VI - C	505-507	458	508	509		459
BOILER FEEDWATER ECONOMIZER	7770	1	VI - C	500-502	458	503	504		459
BOILER FEEDWATER ECONOMIZER	8028	2	VI - C	515-517	458	518	519		459
BOILER FEEDWATER ECONOMIZER	8028	1	VI - C	510-512	458	513	514		459
BOILER FEEDWATER ECONOMIZER	8874	1	VI - C	520-522	458	523	524		459
BOILER FEEDWATER ECONOMIZER	8874	2	VI - C	525-527	458	528	529		459
BOILER FEEDWATER ECONOMIZER	8977	1	VI - C	530-532	458	533	534		459
BOILER OPTIMIZATION	115	2	IV - B	2	1		7		
BOILER OPTIMIZATION	7105	3	IV - B	9	1		14		
BOILER OPTIMIZATION	7153	1	IV - B	16	1		20		
BOILER OPTIMIZATION	7291		IV - B	22	1		26		
BOILER OPTIMIZATION	7579	1	IV - B	28	1		33		
BOILER OPTIMIZATION	7579	2	IV - B	35	1		39		
BOILER OPTIMIZATION	7770	1	IV - B	41	1		45		
BOILER OPTIMIZATION	7770	2	IV - B	47	1		51		
BOILER OPTIMIZATION	8028	1	IV - B	53	1		57		
BOILER OPTIMIZATION	8028	2	IV - B	59	1		64		
BOILER OPTIMIZATION	8874	1	IV - B	66	1		70		
BOILER OPTIMIZATION	8874	2	IV - B	72	1		76		
BOILER OPTIMIZATION	8977	1	IV - B	78	1		82		
BOILER OPTIMIZATION	8977	2	IV - B	84	1		87		
BOILER TESTING	115	2	XI - F		51-56			57,58	
BOILER TESTING	3624	2	XI - F		51-56			61,62	
BOILER TESTING	3624	4	XI - F		51-56			65,66	
BOILER TESTING	3624	1	XI - F		51-56			59,60	

I N D E X

ECO Title	B/C #	Vol #	App	ECO Page	RESULTS Page	COST EST Page	ECIP Page	TEST Page	TABLE Page
BOILER TESTING	3624	3	XI - F		51-56			63,64	
BOILER TESTING	4725	2	XI - F		51-56			69,70	
BOILER TESTING	4725	1	XI - F		51-56			67,68	
BOILER TESTING	4725	3	XI - F		51-56			71,72	
BOILER TESTING	7105	1	XI - F		51-56			73,74	
BOILER TESTING	7105	3	XI - F		51-56			77,78	
BOILER TESTING	7105	2	XI - F		51-56			75,76	
BOILER TESTING	7105	4	XI - F		51-56			79,80	
BOILER TESTING	7153	1	XI - F		51-56			81,82	
BOILER TESTING	7291	1	XI - F		51-56			83,84	
BOILER TESTING	7291	2	XI - F		51-56			85,86	
BOILER TESTING	7579	2	XI - F		51-56			89,90	
BOILER TESTING	7579	1	XI - F		51-56			87,88	
BOILER TESTING	7579	5	XI - F		51-56			93,94	
BOILER TESTING	7579	4	XI - F		51-56			91,92	
BOILER TESTING	7770	2	XI - F		51-56			97,98	
BOILER TESTING	7770	1	XI - F		51-56			95,96	
BOILER TESTING	7855	1	XI - F		51-56			99,100	
BOILER TESTING	8028	2	XI - F		51-56			103,104	
BOILER TESTING	8028	1	XI - F		51-56			101,102	
BOILER TESTING	8874	1	XI - F		51-56			105,106	
BOILER TESTING	8874	2	XI - F		51-56			107,108	
BOILER TESTING	8977	2	XI - F		51-56			111,112	
BOILER TESTING	8977	1	XI - F		51-56			109,110	
BOILER TUNE-UP	115	2	V - C	3	1	5	6		2
BOILER TUNE-UP	3624	2	V - C	11,12	1	13	14		2
BOILER TUNE-UP	3624	3	V - C	15,16	1	17	18		2
BOILER TUNE-UP	3624	4	V - C	19,20	1	21	22		2
BOILER TUNE-UP	3624	1	V - C	7,8	1	9	10		2
BOILER TUNE-UP	4725	3	V - C	31,32	1	33	34		2
BOILER TUNE-UP	4725	2	V - C	27,28	1	29	30		2
BOILER TUNE-UP	4725	1	V - C	23,24	1	25	26		2
BOILER TUNE-UP	7105	4	V - C	47,48	1	49	50		2
BOILER TUNE-UP	7105	2	V - C	39,40	1	41	42		2
BOILER TUNE-UP	7105	3	V - C	43,44	1	45	46		2
BOILER TUNE-UP	7105	1	V - C	35,36	1	37	38		2
BOILER TUNE-UP	7153	1	V - C	51,52	1	53	54		2
BOILER TUNE-UP	7579	2	V - C	55,56	1	57	58		2
BOILER TUNE-UP	7770	2	V - C	59,60	1	61	62		2
BOILER TUNE-UP	8028	2	V - C	67,68	1	69	70		2
BOILER TUNE-UP	8028	1	V - C	63,64	1	65	66		2
BOILER TUNE-UP	8874	2	V - C	75,76	1	77	78		2
BOILER TUNE-UP	8874	1	V - C	71,72	1	73	74		2
BOILER TUNE-UP	8977	2	V - C	83,84	1	85	86		2
BOILER TUNE-UP	8977	1	V - C	79,80	1	81	82		2
BURNER REPLACEMENT	115	2	V - C	89,90	87	91	92		88
BURNER REPLACEMENT	7105	2	V - C	97,98	87	99	100		88
BURNER REPLACEMENT	7105	1	V - C	93,94	87	95	96		88
BURNER REPLACEMENT	7105	3	V - C	101,102	87	103	104		88
BURNER REPLACEMENT	7105	4	V - C	105,106	87	107	108		88
BURNER REPLACEMENT	7153	1	V - C	109,110	87	111	112		88
BURNER REPLACEMENT	7579	2	V - C	117,118	87	119	120		88
BURNER REPLACEMENT	7579	1	V - C	113,114	87	115	116		88
BURNER REPLACEMENT	7770	1	V - C	121,122	87	123	124		88

I N D E X

ECO Title	B/C	#	Vol	App	ECO Page	RESULTS Page	COST EST Page	ECIP Page	TEST Page	TABLE Page
BURNER REPLACEMENT	7770	2	V	- C	125,126	87	127	128		88
BURNER REPLACEMENT	8028	1	V	- C	129,130	87	131	132		88
BURNER REPLACEMENT	8028	2	V	- C	133,134	87	135	136		88
BURNER REPLACEMENT	8874	2	V	- C	141,142	87	143	144		88
BURNER REPLACEMENT	8874	1	V	- C	137,138	87	139	140		88
BURNER REPLACEMENT	8977	2	V	- C	149,150	87	151	152		88
BURNER REPLACEMENT	8977	1	V	- C	145,146	87	147	148		88
CENTRAL CHILLED WATER PLANTS		N	II	- 3	5					
CENTRIFUGAL CHILLER REPLACEMENT	5250	2	IX	- D	352,353	351	354	355		
CHILLED WATER TEMPERATURE RESET	3220	1	IX	- D	442,443	441	444	445		
CHILLED WATER TEMPERATURE RESET	3305	1	IX	- D	446,447	441	448	449		
CHILLED WATER TEMPERATURE RESET	4484	1	IX	- D	450,451	441	452	453		
CHILLED WATER TEMPERATURE RESET	4488	2	IX	- D	454,455	441	456	457		
CHILLED WATER TEMPERATURE RESET	5250	1	IX	- D	458,459	441	460	461		
CHILLED WATER TEMPERATURE RESET	5250	2	IX	- D	462,463	441	464	465		
CHILLED WATER TEMPERATURE RESET	5400	1	IX	- D	466,467	441	468	469		
CHILLED WATER TEMPERATURE RESET	5681	1	IX	- D	470,471	441	472	473		
CHILLED WATER TEMPERATURE RESET	5681	2	IX	- D	474,475	441	476	477		
CHILLED WATER TEMPERATURE RESET	5681	3	IX	- D	478,479	441	480	481		
CHILLED WATER TEMPERATURE RESET	7120	1	IX	- D	482,483	441	484	485		
CHILLED WATER TEMPERATURE RESET	7770	1	IX	- D	486,487	441	488	489		
CHILLER ECONOMIZER	109	1	IV	- B	141	131		143		
CHILLER ECONOMIZER	3485	1	IV	- B	137	131		139		
CHILLER ECONOMIZER	4500	1	IV	- B	132	131		135		
CHILLER OPTIMIZATION	3220	1	IV	- B	91	90		94		
CHILLER OPTIMIZATION	4484	1	IV	- B	96	90		99		
CHILLER OPTIMIZATION	4488	2	IV	- B	101	90		104		
CHILLER OPTIMIZATION	5250	1	IV	- B	106	90		109		
CHILLER OPTIMIZATION	5681	1	IV	- B	111	90		114		
CHILLER OPTIMIZATION	5681	2	IV	- B	116	90		119		
CHILLER OPTIMIZATION	5681	3	IV	- B	121	90		124		
CHILLER OPTIMIZATION	7120	1	IV	- B	126	90		129		
CHILLER SHUTDOWN	3220	1	IX	- D	289,290	288	291	292		
CHILLER SHUTDOWN	4484	1	IX	- D	293,294	288	295	296		
CHILLER SHUTDOWN	4488	2	IX	- D	297,298	288	299	300		
CHILLER SHUTDOWN	5250	1	IX	- D	301,302	288	303	304		
CHILLER SHUTDOWN	7120	1	IX	- D	305,306	288	307	308		
CHILLER TESTING	109	1	XI	- F		1,2			3-5	
CHILLER TESTING	3220	1	XI	- F		1,2			6-8	
CHILLER TESTING	3305	1	XI	- F		1,2			9-11	
CHILLER TESTING	3305	2	XI	- F		1,2			12-14	
CHILLER TESTING	3485	1	XI	- F		1,2			15-17	
CHILLER TESTING	4484	1	XI	- F		1,2			18-20	
CHILLER TESTING	4488	2	XI	- F		1,2			24-26	
CHILLER TESTING	4488	1	XI	- F		1,2			21-23	
CHILLER TESTING	4505	1	XI	- F		1,2			27-29	
CHILLER TESTING	5250	2	XI	- F		1,2			33-35	
CHILLER TESTING	5250	1	XI	- F		1,2			30-32	
CHILLER TESTING	5400	1	XI	- F		1,2			36-38	
CHILLER TESTING	5681	2	XI	- F		1,2			42-44	
CHILLER TESTING	5681	1	XI	- F		1,2			39-41	
CHILLER TESTING	7120	1	XI	- F		1,2			45-47	
CHILLER TESTING	7770	1	XI	- F		1,2			48-50	
COMPLETE CHILLER OPTIMIZATION	5400	1	IV	- B	146	145		150		

I N D E X

ECO Title	B/C	#	Vol #	App	ECO Page	RESULTS Page	COST EST Page	ECIP Page	TEST Page	TABLE Page
COMPLETE CHILLER OPTIMIZATION	7770	1	IV - B		152	145		156		
CONCLUSIONS		Ex	I -		8					
CONCLUSIONS		N	II - 6		1					
CONDENSER TUBE CLEANING	109	1	VIII - D		2,3	1	4	5		
CONDENSER TUBE CLEANING	3220	1	VIII - D		6,7	1	8	9		
CONDENSER TUBE CLEANING	3305	2	VIII - D		14,15	1	16	17		
CONDENSER TUBE CLEANING	3305	1	VIII - D		10,11	1	12	13		
CONDENSER TUBE CLEANING	3485	1	VIII - D		18,19	1	20	21		
CONDENSER TUBE CLEANING	4484	1	VIII - D		22,23	1	24	25		
CONDENSER TUBE CLEANING	4488	1	VIII - D		26,27	1	28	29		
CONDENSER TUBE CLEANING	4488	2	VIII - D		30,31	1	32	33		
CONDENSER TUBE CLEANING	4500	1	VIII - D		34,35	1	36	37		
CONDENSER TUBE CLEANING	4505	1	VIII - D		38,39	1	40	41		
CONDENSER TUBE CLEANING	5250	1	VIII - D		42,43	1	44	45		
CONDENSER TUBE CLEANING	5250	2	VIII - D		46,47	1	48	49		
CONDENSER TUBE CLEANING	5400	3	VIII - D		58,59	1	60	61		
CONDENSER TUBE CLEANING	5400	2	VIII - D		54,55	1	56	57		
CONDENSER TUBE CLEANING	5400	1	VIII - D		50,51	1	52	53		
CONDENSER TUBE CLEANING	5681	2	VIII - D		66,67	1	68	69		
CONDENSER TUBE CLEANING	5681	3	VIII - D		70,71	1	72	73		
CONDENSER TUBE CLEANING	5681	1	VIII - D		62,63	1	64	65		
CONDENSER TUBE CLEANING	7120	1	VIII - D		74,75	1	76	77		
CONDENSER TUBE CLEANING	7770	1	VIII - D		78,79	1	80	81		
CONTRACT SCOPE OF WORK			III - A		1					
CORRESPONDENCE			III - A		26					
DOWNSIZE BOILERS	115	2	VI - C		301,302	299	303	304		300
DOWNSIZE BOILERS	7105	4	VI - C		317,318	299	319	320		300
DOWNSIZE BOILERS	7105	3	VI - C		313,314	299	315	316		300
DOWNSIZE BOILERS	7105	2	VI - C		309,310	299	311	312		300
DOWNSIZE BOILERS	7105	1	VI - C		305,306	299	307	308		300
DOWNSIZE BOILERS	7153	1	VI - C		321,322	299	323	324		300
DOWNSIZE BOILERS	7770	2	VI - C		329,330	299	331	332		300
DOWNSIZE BOILERS	7770	1	VI - C		325,326	299	327	328		300
DOWNSIZE BOILERS	8977	1	VI - C		333,334	299	335,336	337		300
DOWNSIZE BOILERS	8977	2	VI - C		338,339	299	340,341	342		300
ECO DESCRIPTIONS		N	II - 4		2					
ECOs ANALYSES		Ex	I -		2					
ECOs NOT APPLICABLE		N	II - 4		18					
ENERGY CONSERVATION OPPORTUNITIES		Ex	I -		2					
ENERGY CONSERVATION OPPORTUNITIES CONSIDERED		N	II - 4		1					
ENERGY CONSERVATION OPPORTUNITIES EVALUATED		N	II - 4		1					
ENERGY STUDIES BY OTHERS		N	II - 5		1					
EXISTING CONDITIONS		N	II - 2		1					
EXISTING EQUIPMENT CONDITIONS		N	II - 2		10					
EXISTING INSTALLATION EQUIPMENT		N	II - 3		4					
FIELD SURVEY		N	II - 2		1					
INSTALLATION OF TURBULATORS	115	2	VII - C		770	769	771	772		
INSTALLATION OF TURBULATORS	7105	1	VII - C		773	769	774	775		
INSTALLATION OF TURBULATORS	7105	3	VII - C		779	769	780	781		
INSTALLATION OF TURBULATORS	7105	4	VII - C		782	769	783	784		
INSTALLATION OF TURBULATORS	7105	2	VII - C		776	769	777	778		
INSTALLATION OF TURBULATORS	7153	1	VII - C		785	769	786	787		
INSTALLATION OF TURBULATORS	7579	1	VII - C		788	769	789	790		
INSTALLATION OF TURBULATORS	7579	2	VII - C		791	769	792	793		

I N D E X

ECO Title	B/C #	Vol #	App	ECO Page	RESULTS Page	COST EST Page	ECIP Page	TEST Page	TABLE Page
INSTALLATION OF TURBULATORS	7770	2	VII - C	797	769	798	799		
INSTALLATION OF TURBULATORS	7770	1	VII - C	794	769	795	796		
INSTALLATION OF TURBULATORS	8028	1	VII - C	800	769	801	802		
INSTALLATION OF TURBULATORS	8028	2	VII - C	803	769	804	805		
INSTALLATION OF TURBULATORS	8874	2	VII - C	809	769	810	811		
INSTALLATION OF TURBULATORS	8874	1	VII - C	806	769	807	808		
INSTALLATION OF TURBULATORS	8977	1	VII - C	812	769	813	814		
INSTALLATION OF TURBULATORS	8977	2	VII - C	815	769	816	817		
INTRODUCTION	N	II	- 1	1					
INTRODUCTION - Executive Summary	Ex	I	-	1					
OPERATION AND MAINTENANCE RECOMMENDATIONS	N	II	- 4	8					
ORGANIZATIONAL TABLE FOR ECOS	N	II	- 4	1					
OVERVIEW OF TECHNICAL APPROACH	N	II	- 1	2					
OXYGEN TRIM SYSTEM	115	2	VII - C	640-643	638	644	645		639
OXYGEN TRIM SYSTEM	7105	4	VII - C	664-667	638	668	669		639
OXYGEN TRIM SYSTEM	7105	1	VII - C	646-649	638	650	651		639
OXYGEN TRIM SYSTEM	7105	2	VII - C	652-655	638	656	657		639
OXYGEN TRIM SYSTEM	7105	3	VII - C	658-661	638	662	663		639
OXYGEN TRIM SYSTEM	7153	1	VII - C	670-673	638	674	675		639
OXYGEN TRIM SYSTEM	7579	2	VII - C	682-685	638	686	687		639
OXYGEN TRIM SYSTEM	7579	1	VII - C	676-679	638	680	681		639
OXYGEN TRIM SYSTEM	7770	1	VII - C	688-691	638	692	693		639
OXYGEN TRIM SYSTEM	7770	2	VII - C	694-697	638	698	699		639
OXYGEN TRIM SYSTEM	8028	2	VII - C	706-709	638	710	711		639
OXYGEN TRIM SYSTEM	8028	1	VII - C	700-703	638	704	705		639
OXYGEN TRIM SYSTEM	8874	1	VII - C	712-715	638	716	717		639
OXYGEN TRIM SYSTEM	8874	2	VII - C	718-721	638	722	723		639
OXYGEN TRIM SYSTEM	8977	1	VII - C	724-727	638	728	729		639
OXYGEN TRIM SYSTEM	8977	2	VII - C	730-733	638	734	735		639
PERFORMANCE TESTING	N	II	- 3	1					
PREHEAT COMBUSTION AIR	115	2	VI - C	365-367	363	368	369		364
PREHEAT COMBUSTION AIR	7105	4	VI - C	385-387	363	388	389		364
PREHEAT COMBUSTION AIR	7105	1	VI - C	370-372	363	373	374		364
PREHEAT COMBUSTION AIR	7105	2	VI - C	375-377	363	378	379		364
PREHEAT COMBUSTION AIR	7105	3	VI - C	380-382	363	383	384		364
PREHEAT COMBUSTION AIR	7153	1	VI - C	390-392	363	393	394		364
PREHEAT COMBUSTION AIR	7579	1	VI - C	395-397	363	398	399		364
PREHEAT COMBUSTION AIR	7579	2	VI - C	400-402	363	403	404		364
PREHEAT COMBUSTION AIR	7770	1	VI - C	405-407	363	408	409		364
PREHEAT COMBUSTION AIR	7770	2	VI - C	410-412	363	413	414		364
PREHEAT COMBUSTION AIR	8028	2	VI - C	420-422	363	423	424		364
PREHEAT COMBUSTION AIR	8028	1	VI - C	415-417	363	418	419		364
PREHEAT COMBUSTION AIR	8874	1	VI - C	425-427	363	428	429		364
PREHEAT COMBUSTION AIR	8874	2	VI - C	430-432	363	433	434		364
PREHEAT COMBUSTION AIR	8977	2	VI - C	440-442	363	443	444		364
PREHEAT COMBUSTION AIR	8977	1	VI - C	435-437	363	438	439		364
PURPOSE AND OBJECTIVE	N	II	- 1	1					
RECOMMENDATIONS	N	II	- 7	1					
RECOMMENDATIONS	Ex	I	-	16					
REPLACEMENT BOILER	115	2	V - C	175,176	173	177	178		174
REPLACEMENT BOILER	7105	2	V - C	183,184	173	185	186		174
REPLACEMENT BOILER	7105	4	V - C	215,216	173	217	218		174
REPLACEMENT BOILER	7105	1	V - C	179,180	173	181	182		174
REPLACEMENT BOILER	7153	1	V - C	187,188	173	189	190		174

I N D E X

ECO Title	B/C #	Vol #	App	ECO Page	RESULTS Page	COST EST Page	ECIP Page	TEST Page	TABLE Page
REPLACEMENT BOILER	7579 2	V - C		195,196	173	197	198		174
REPLACEMENT BOILER	7579 1	V - C		191,192	173	193	194		174
REPLACEMENT BOILER	7770 1	V - C		199,200	173	201	202		174
REPLACEMENT BOILER	7770 2	V - C		203,204	173	205	206		174
REPLACEMENT BOILER	8028 1	V - C		211,212	173	213	214		174
REPLACEMENT BOILER	8874 2	V - C		207,208	173	209	210		174
REPLACEMENT BOILER	8977 2	V - C		224,225	173	226,227	228		174
REPLACEMENT BOILER	8977 1	V - C		219,220	173	221,222	223		174
RESULTS	Ex	I -		8					
RESULTS, CONCLUSIONS, AND RECOMMENDATIONS	Ex	I -		8					
SCOPE	Ex	I -		1					
SCOPE OF WORK	N	II -	1	1					
STEAM VS. ELECTRICALLY DRIVEN CHILLERS	3220 1	IX - D		357,358	356	359	360		
STEEL FEEDWATER ECONOMIZER	115 2	VII - C		551-553	549	554	555		550
STEEL FEEDWATER ECONOMIZER	7105 3	VII - C		566-568	549	569	570		550
STEEL FEEDWATER ECONOMIZER	7105 2	VII - C		561-563	549	564	565		550
STEEL FEEDWATER ECONOMIZER	7105 4	VII - C		571-573	549	574	574		550
STEEL FEEDWATER ECONOMIZER	7105 1	VII - C		556-558	549	559	560		550
STEEL FEEDWATER ECONOMIZER	7153 1	VII - C		576-578	549	579	580		550
STEEL FEEDWATER ECONOMIZER	7579 1	VII - C		581-583	549	584	585		550
STEEL FEEDWATER ECONOMIZER	7579 2	VII - C		586-588	549	589	590		550
STEEL FEEDWATER ECONOMIZER	7770 1	VII - C		591-593	549	594	595		550
STEEL FEEDWATER ECONOMIZER	7770 2	VII - C		596-598	549	599	600		550
STEEL FEEDWATER ECONOMIZER	8028 2	VII - C		606-608	549	609	610		550
STEEL FEEDWATER ECONOMIZER	8028 1	VII - C		601-603	549	604	605		550
STEEL FEEDWATER ECONOMIZER	8874 2	VII - C		616-618	549	619	620		550
STEEL FEEDWATER ECONOMIZER	8874 1	VII - C		611-613	549	614	615		550
STEEL FEEDWATER ECONOMIZER	8977 1	VII - C		621-623	549	624	625		550
SUMMER BOILER INSTALLATION	115	V - C		251,252	249	253	254		250
SUMMER BOILER INSTALLATION	7153	V - C		255,256	249	257	258		250
SUMMER BOILER INSTALLATION	7291	V - C		259,260	249	261	262		250
SUMMER BOILER INSTALLATION	7579	V - C		263,264	249	265	266		250
SUMMER BOILER INSTALLATION	7770	V - C		267,268	249	269	270		250
SUMMER BOILER INSTALLATION	7855	V - C		271,272	249	273	274		250
SUMMER BOILER INSTALLATION	8874	V - C		275,276	249	277	278		250
TECHNICAL APPROACH	Ex	I -		2					
TESTED COMBUSTION EFFICIENCY	115 2	X - E		1,2					
TESTED COMBUSTION EFFICIENCY	3624 3	X - E		7,8					
TESTED COMBUSTION EFFICIENCY	3624 4	X - E		9,10					
TESTED COMBUSTION EFFICIENCY	3624 2	X - E		5,6					
TESTED COMBUSTION EFFICIENCY	3624 1	X - E		3,4					
TESTED COMBUSTION EFFICIENCY	4725 1	X - E		11,12					
TESTED COMBUSTION EFFICIENCY	4725 2	X - E		13,14					
TESTED COMBUSTION EFFICIENCY	4725 3	X - E		15,16					
TESTED COMBUSTION EFFICIENCY	7105 3	X - E		21,22					
TESTED COMBUSTION EFFICIENCY	7105 2	X - E		19,20					
TESTED COMBUSTION EFFICIENCY	7105 1	X - E		17,18					
TESTED COMBUSTION EFFICIENCY	7105 4	X - E		23,24					
TESTED COMBUSTION EFFICIENCY	7153 1	X - E		25,26					
TESTED COMBUSTION EFFICIENCY	7291 2	X - E		29,30					
TESTED COMBUSTION EFFICIENCY	7291 1	X - E		27,28					
TESTED COMBUSTION EFFICIENCY	7579 1	X - E		31,32					
TESTED COMBUSTION EFFICIENCY	7579 5	X - E		37,38					
TESTED COMBUSTION EFFICIENCY	7579 2	X - E		33,34					

I N D E X

ECO Title	B/C #	Vol #	App	ECO Page	RESULTS Page	COST EST Page	ECIP Page	TEST Page	TABLE Page
TESTED COMBUSTION EFFICIENCY	7579	4	X - E	35,36					
TESTED COMBUSTION EFFICIENCY	7770	1	X - E	39,40					
TESTED COMBUSTION EFFICIENCY	7770	2	X - E	41,42					
TESTED COMBUSTION EFFICIENCY	7855	1	X - E	43,44					
TESTED COMBUSTION EFFICIENCY	8028	1	X - E	45,46					
TESTED COMBUSTION EFFICIENCY	8028	2	X - E	47,48					
TESTED COMBUSTION EFFICIENCY	8874	2	X - E	51,52					
TESTED COMBUSTION EFFICIENCY	8874	1	X - E	49,50					
TESTED COMBUSTION EFFICIENCY	8977	2	X - E	55,56					
TESTED COMBUSTION EFFICIENCY	8977	1	X - E	53,54					
TUNED FOR AVERAGE LOAD CONDITIONS	115	2	X - E	107,108					
TUNED FOR AVERAGE LOAD CONDITIONS	3624	2	X - E	111,112					
TUNED FOR AVERAGE LOAD CONDITIONS	3624	1	X - E	109,110					
TUNED FOR AVERAGE LOAD CONDITIONS	3624	3	X - E	113,114					
TUNED FOR AVERAGE LOAD CONDITIONS	3624	4	X - E	115,116					
TUNED FOR AVERAGE LOAD CONDITIONS	4725	3	X - E	121,122					
TUNED FOR AVERAGE LOAD CONDITIONS	4725	1	X - E	117,118					
TUNED FOR AVERAGE LOAD CONDITIONS	4725	2	X - E	119,120					
TUNED FOR AVERAGE LOAD CONDITIONS	4725	4	X - E	123,124					
TUNED FOR AVERAGE LOAD CONDITIONS	7105	2	X - E	127,128					
TUNED FOR AVERAGE LOAD CONDITIONS	7105	3	X - E	129,130					
TUNED FOR AVERAGE LOAD CONDITIONS	7105	1	X - E	125,126					
TUNED FOR AVERAGE LOAD CONDITIONS	7105	4	X - E	131,132					
TUNED FOR AVERAGE LOAD CONDITIONS	7153	1	X - E	133,134					
TUNED FOR AVERAGE LOAD CONDITIONS	7291	2	X - E	137,138					
TUNED FOR AVERAGE LOAD CONDITIONS	7291	1	X - E	135,136					
TUNED FOR AVERAGE LOAD CONDITIONS	7579	2	X - E	141,142					
TUNED FOR AVERAGE LOAD CONDITIONS	7579	1	X - E	139,140					
TUNED FOR AVERAGE LOAD CONDITIONS	7770	1	X - E	143,144					
TUNED FOR AVERAGE LOAD CONDITIONS	7770	2	X - E	145,146					
TUNED FOR AVERAGE LOAD CONDITIONS	7855	2	X - E	149,150					
TUNED FOR AVERAGE LOAD CONDITIONS	7855	1	X - E	147,148					
TUNED FOR AVERAGE LOAD CONDITIONS	8028	2	X - E	153,154					
TUNED FOR AVERAGE LOAD CONDITIONS	8028	1	X - E	151,152					
TUNED FOR AVERAGE LOAD CONDITIONS	8874	1	X - E	155,156					
TUNED FOR AVERAGE LOAD CONDITIONS	8874	2	X - E	157,158					
TUNED FOR AVERAGE LOAD CONDITIONS	8977	2	X - E	161,162					
TUNED FOR AVERAGE LOAD CONDITIONS	8977	1	X - E	159,160					
TUNED FOR SUMMER LOAD CONDITIONS	115	2	X - E	163,164					
TUNED FOR SUMMER LOAD CONDITIONS	3624	4	X - E	165,166					
TUNED FOR SUMMER LOAD CONDITIONS	4725	4	X - E	167,168					
TUNED FOR SUMMER LOAD CONDITIONS	7153	1	X - E	169,170					
TUNED FOR SUMMER LOAD CONDITIONS	7291	1	X - E	171,172					
TUNED FOR SUMMER LOAD CONDITIONS	7579	1	X - E	173,174					
TUNED FOR SUMMER LOAD CONDITIONS	7770	1	X - E	175,176					
TUNED FOR SUMMER LOAD CONDITIONS	7855	1	X - E	177,178					
TUNED FOR SUMMER LOAD CONDITIONS	8874	2	X - E	179,180					
TUNED FOR TESTED LOAD CONDITIONS	115	2	X - E	57,58					
TUNED FOR TESTED LOAD CONDITIONS	3624	1	X - E	59,60					
TUNED FOR TESTED LOAD CONDITIONS	3624	4	X - E	65,66					
TUNED FOR TESTED LOAD CONDITIONS	3624	3	X - E	63,64					
TUNED FOR TESTED LOAD CONDITIONS	3624	2	X - E	61,62					
TUNED FOR TESTED LOAD CONDITIONS	4725	2	X - E	69,70					
TUNED FOR TESTED LOAD CONDITIONS	4725	1	X - E	67,68					

I N D E X

ECO Title	B/C #	Vol #	App	ECO Page	RESULTS Page	COST EST Page	ECIP Page	TEST Page	TABLE Page
TUNED FOR TESTED LOAD CONDITIONS	4725	3	X - E	71,72					
TUNED FOR TESTED LOAD CONDITIONS	7105	4	X - E	79,80					
TUNED FOR TESTED LOAD CONDITIONS	7105	2	X - E	75,76					
TUNED FOR TESTED LOAD CONDITIONS	7105	3	X - E	77,78					
TUNED FOR TESTED LOAD CONDITIONS	7105	2	X - E	85,86					
TUNED FOR TESTED LOAD CONDITIONS	7105	1	X - E	73,74					
TUNED FOR TESTED LOAD CONDITIONS	7153	1	X - E	81,82					
TUNED FOR TESTED LOAD CONDITIONS	7291	1	X - E	83,84					
TUNED FOR TESTED LOAD CONDITIONS	7579	2	X - E	87,88					
TUNED FOR TESTED LOAD CONDITIONS	7579	4	X - E	89,90					
TUNED FOR TESTED LOAD CONDITIONS	7770	2	X - E	91,92					
TUNED FOR TESTED LOAD CONDITIONS	7855	1	X - E	93,94					
TUNED FOR TESTED LOAD CONDITIONS	8028	2	X - E	97,98					
TUNED FOR TESTED LOAD CONDITIONS	8028	1	X - E	95,96					
TUNED FOR TESTED LOAD CONDITIONS	8874	1	X - E	99,100					
TUNED FOR TESTED LOAD CONDITIONS	8874	2	X - E	101,102					
TUNED FOR TESTED LOAD CONDITIONS	8977	2	X - E	105,106					
TUNED FOR TESTED LOAD CONDITIONS	8977	1	X - E	103,104					
TWO-SPEED COOLING TOWER FAN	109	1	IX - D	310,311	309	312	313-316		
TWO-SPEED COOLING TOWER FAN	3220	1	IX - D	317,318	309	319	320-323		
TWO-SPEED COOLING TOWER FAN	3485	1	IX - D	324,325	309	326	327-330		
TWO-SPEED COOLING TOWER FAN	4500	1	IX - D	330A,330B	309	330C	330D,330E		
TWO-SPEED COOLING TOWER FAN	4505	1	IX - D	331,332	309	333	334-337		
TWO-SPEED COOLING TOWER FAN	7770	1	IX - D	338,339	309	340	341-344		
UTILITY RATES		N	II - 2	3					
VARIABLE SPEED FANS	3624	4	VII - C	754	742	755	756		743,744
VARIABLE SPEED FANS	3624	1	VII - C	745	742	746	747		743,744
VARIABLE SPEED FANS	3624	2	VII - C	748	742	749	750		743,744
VARIABLE SPEED FANS	3624	3	VII - C	751	742	752	753		743,744
VARIABLE SPEED FANS	4725	4	VII - C	766	742	767	768		743,744
VARIABLE SPEED FANS	4725	2	VII - C	760	742	761	762		743,744
VARIABLE SPEED FANS	4725	3	VII - C	763	742	764	765		743,744
VARIABLE SPEED FANS	4725	1	VII - C	757	742	758	759		743,744
VARIABLE SPEED PUMPING	3220	1	IX - D	494,495	493	497,498	499		
VARIABLE SPEED PUMPING	3485	1	IX - D	500,501	493	503,504	505		
VARIABLE SPEED PUMPING	4484	1	IX - D	506,507	493	509,510	511		
VARIABLE SPEED PUMPING	5681	1	IX - D	512,513	493	515,516	517		
WATER TREATMENT/FILL REPLACEMENT	109	1	VIII - D	201,202	200	203,204	205		
WATER TREATMENT/FILL REPLACEMENT	3220	1	VIII - D	206,207	200	208,209	210		
WATER TREATMENT/FILL REPLACEMENT	3305	2	VIII - D	216,217	200	218,219	220		
WATER TREATMENT/FILL REPLACEMENT	3305	1	VIII - D	211,212	200	213,214	215		
WATER TREATMENT/FILL REPLACEMENT	3485	1	VIII - D	221,222	200	223,224	225		
WATER TREATMENT/FILL REPLACEMENT	4488	1	VIII - D	226,227	200	228,229	230		
WATER TREATMENT/FILL REPLACEMENT	4488	2	VIII - D	231,232	200	233,234	235		
WATER TREATMENT/FILL REPLACEMENT	4500	1	VIII - D	236,237	200	238,239	240		
WATER TREATMENT/FILL REPLACEMENT	4505	1	VIII - D	241,242	200	243,244	245		
WATER TREATMENT/FILL REPLACEMENT	5250	1	VIII - D	246,247	200	248,249	250		
WATER TREATMENT/FILL REPLACEMENT	5400	1	VIII - D	251,252	200	253,254	255		
WATER TREATMENT/FILL REPLACEMENT	5400	2	VIII - D	256,257	200	258,259	260		
WATER TREATMENT/FILL REPLACEMENT	5681	1	VIII - D	261,262	200	263,264	265		
WATER TREATMENT/FILL REPLACEMENT	7120	1	VIII - D	266,267	200	268,269	270		
WATER TREATMENT/FILL REPLACEMENT	7770	1	VIII - D	271,272	200	273,274	275		
WATERSIDE ECONOMIZER	109	1	IX - D	365,366	364	368	369		
WATERSIDE ECONOMIZER	3220	1	IX - D	370,371	364	373	374		

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ECO Title	B/C #	Vol #	App	ECO Page	RESULTS Page	COST EST Page	ECIP Page	TEST Page	TABLE Page
WATERSIDE ECONOMIZER	3305	1	IX - D	375,376	364	378	379		
WATERSIDE ECONOMIZER	3485	1	IX - D	380,381	364	383	384		
WATERSIDE ECONOMIZER	4484	1	IX - D	385,386	364	388	389		
WATERSIDE ECONOMIZER	4488	1	IX - D	390,391	364	393	394		
WATERSIDE ECONOMIZER	4500	1	IX - D	395,396	364	398	399		
WATERSIDE ECONOMIZER	4505	1	IX - D	400,401	364	403	404		
WATERSIDE ECONOMIZER	5250	1	IX - D	405,406	364	408	409		
WATERSIDE ECONOMIZER	5400	3	IX - D	410,411	364	413	414		
WATERSIDE ECONOMIZER	5681	1	IX - D	415,416	364	418	419		
WATERSIDE ECONOMIZER	7120	1	IX - D	420,421	364	423	424		
WATERSIDE ECONOMIZER	7770	1	IX - D	425,426	364	428	429		
WORK ACCOMPLISHED	N	II	- 3		1				